Department of Bioscience & Biotechnology

Banasthali Vidyapith, Banasthali

Minutes of the Board of Studies held on June 19, 2021 at 11.00am through Online Mode.

Present

1. Prof. Partha Roy	External Member
2. Dr. Tapan Kumar Mondal	External Member
3. Prof. Ansuman Lahiri	External Member
4. Prof. C.K. Jha	Special Invitee
5. Prof. Shalini Chandra	Special Invitee
6. Dr. Afroz Alam	Internal Member
7. Shri Anand Prakash	Internal Member
8. Dr. Arindam Kuila	Internal Member
9. Dr. Arun Kumar Sharma	Internal Member
10. Prof. Dipjyoti Chakraborty	Convener (in the Chair)
11. Dr. Girish Chandra Pandey	Internal Member
12. Dr. Istkhar	Internal Member
13. Dr. Jyoti Mathur	Internal Member
14. Dr. Kakoli Dutt	Internal Member
15. Dr. Laxmi Parwani	Internal Member
16. Dr. Manoj Kumar	Internal Member
17. Dr. Md. Azizur Rahman	Internal Member
18. Dr. Narendra Kumar Sharma	Internal Member
19. Prof. Nilima Kumari	Internal Member
20. Ms. Poornima Pandey	Internal Member
21. Dr. Pracheta	Internal Member
22. Dr. Priyanka Singh	Internal Member
23. Dr. Rajabrata Bhuyan	Internal Member
24. Dr. Rashmi Tripathi	Internal Member
25. Dr. Sangeeta Choudhary	Internal Member
26. Dr. Sarika Gupta	Internal Member
27. Dr. Sharad Vats	Internal Member
28. Dr. Suphiya Khan	Internal Member
29. Dr. Supriyo Basak	Internal Member
30. Dr. Surbhi Bajpai	Internal Member
31. Dr. Swati Paliwal	Internal Member
32. Dr. Teena Agrawal	Internal Member
33. Ms. Tripti Sharma	Internal Member
34. Prof. Veena Sharma	Internal Member

The following Internal members: Shri. Anand Prakash, Dr. Laxmi Parwani, Dr. Priyanka Singh, Dr. Suphiya Khan, Dr. Surbhi Bajpai, Dr. Swati Paliwal, Ms. Tripti Sharma and the following Invitees: Prof. CK Jha and Prof. Shalini Chandra could not attend the meeting.

The meeting started with a welcome of the members, by the Convener of Board of Studies for Bioscience and Biotechnology, Prof. Dipjyoti Chakarborty, Head, Department of Bioscience and Biotechnology, Banasthali Vidyapith, Rajasthan.

Prof. Chakraborty apprised the Board that Prof. Aditya Shastri, Vice Chancellor, Banasthali Vidyapith, a renowned educationalist and 'Chief Architect' of Banasthali as we know today left for his heavenly abode on 24th May, 2021. The Board proposed the following condolence message in the memory and honor of Prof. Aditya Shastri:

The Board of Studies of the Department of Bioscience and Biotechnology and all its members are deeply moved and pained by the unfortunate and untimely demise of Prof. Aditya Shastri and express their deepest condolences

Professor Aditya Shastri was serving as Vice-Chancellor of Banasthali Vidyapith and discharging the duties as Chief Executive Officer and Chief Academic Officer of the University.

In 2003 he was the youngest ever to become Vice-chancellor of an Indian university!

He was born on 4th June, 1963 in a family of academicians where higher education and social service was valued the most. His grandfather Pandit Hiralal Shastri was the First Chief Minister of Rajasthan, a member for the constituent assembly and founded Banasthali Vidyapith in 1935 along with Smt. Ratan Shastri, a recipient of Padma Bhusan and the Jamnalal Bajaj Awards for her contribution to Banasthali.

Prof. Shastri showed a great deal of promise in academics from the very early age and secured 4th rank in the Higher Secondary examination of the Board of Secondary Education, Rajasthan. He was also a rank holder in the Secondary examination securing 8th position. On completion of his education from BITS, Pilani in 1984 from where he received M.Sc.(Tech.) Computer Science and M.Sc. (Hons.) Mathematics, he went to USA for further studies and earned Master's degree in Mathematics from SUNY, Stony Brook, before moving to Massachusetts Institute of Technology (MIT) from where he completed his Ph.D. in 1990.

After serving the Tata Institute of Fundamental Research (TIFR) for one year, he moved to Banasthali where he has remained ever since. His initial years at Banasthali were mainly devoted to developing IT and Computer Science activities which culminated in the establishment of Apaji Institute of Mathematics and Applied Computer Technology (AIM&ACT).

During this period he has held several visiting appointments in the UK, France and Japan; most notably, he was selected as a Marie-Curie Fellow by DST in 1994-95 and spent that year in Universite Du Maine, France. This fellowship is given to only one scientist every year. He was also a Royal Society Exchange Visitor to the University of Nottingham in 1993 and a research staff member at IBM-India Research Lab. from 1999-2000.

He published over 50 research papers and authored five text-books. He has carried out a number of research projects for various funding agencies. He generated well over 25 crores

for Banasthali Vidyapith by way of his individual research grants. His research interests included Discrete Mathematics, Combinatorics, Graph Theory, Theory of Computation, (parallel) algorithms, E-commerce and Mobile Computing.

Of late, he was spending much of his time and energy for the overall development of Banasthali. Over the last few years the Vidyapith has attained self-reliance through some bold initiative spearheaded by him such as the Jaipur campus, off-shore centers and massive expansion of all activities of the Vidyapith. Ever since he joined, the enrollment jumped 10-folds, budget 20-folds, workers 5-folds and Banasthali has witnessed phenomenal growth with an estimated outlay of Rs. 200 crores. Shri Pranab Mukherjee during his convocation address recently remarked that, "Banasthali has grown faster than the Indian GDP since liberalization!"

The University has recently been accredited with 'A++' grade by NAAC, Govt. of India, placed in 'A' category by MHRD Review Committee, made its mark in International Rankings and attracts more number of applications than ever before all due the able leadership of Prof. Shastri.

The Department of Bioscience and Biotechnology has been a proud recipient of Sirs' benevolence and the sprawling new building and excellent research facilities were possible due to his singular innovative input to DST to implement the CURIE programme to uplift Basic Sciences in Womens' universities.

A humble, down to earth person, he always championed the need to recognise women-only universities. He also created a possible framework to further boost the idea of having a methodology to review and encourage such institutions to take shape. In the untimely and unfortunate demise of Prof. Shastri, the world has have lost a true visionary of women empowerment.

The Board discussed and recommended the following:

1. The Board took up for confirmation of the minutes of its last meeting held on December 28, 2019.

   - The Board resolved that the minutes of its last meeting be confirmed.

2. The board updated the panel of examiners for various examinations of Bachelor's and Master's degree in accordance with the Bye-laws 15.3.02 of the Vidyapith. The existing panel will continue to be retained. The updated list of examiners is submitted.

3. The various courses running in the department viz.,

   I. B.Sc. Bioscience,

   II. B.Sc. Biotechnology,

   III. B.Tech. Biotechnology,

IVA. M.Sc. Bioscience (Animal Science),

IVB. M.Sc. Bioscience (Plant Science),

IVC. M.Sc. Applied Microbiology and Biotechnology,

IVD. M.Sc. Biotechnology,

IVE. M.Sc. Bioinformatics,

V. M.Tech. Biotechnology,

VI. Certificate Course in Molecular Modeling and Drug Designing.

VIIA. Diploma in Computational Biology.

VIIB.PG Diploma/Diploma in Bioinformatics were placed before the board, thoroughly discussed and revision proposed as under:

I. B. Sc. Bioscience (Botany and Zoology):

i.	First Semester Examination, December, 2021	No Change
ii.	Second Semester Examination, April/May, 2022	No Change
iii.	Third Semester Examination, December, 2022	No Change
iv.	Fourth Semester Examination, April/May, 2023	No Change
v.	Fifth Semester Examination, December, 2023	No Change
vi.	Sixth Semester Examination, April/May, 2024	No Change

II. B. Sc. Biotechnology:

i.	First Semester Examination, December, 2021	No Change
ii.	Second Semester Examination, April/May, 2022	No Change
iii.	Third Semester Examination, December, 2022	No Change
iv.	Fourth Semester Examination, April/May, 2023	No Change
v.	Fifth Semester Examination, December, 2023	No Change
vi.	Sixth Semester Examination, April/May, 2024	No Change

III. B.Tech. Biotechnology:

i.	First Semester Examination, December, 2021	No Change
ii.	Second Semester Examination, April/May, 2022	No Change
iii.	Third Semester Examination, December, 2022	No Change
iv.	Fourth Semester Examination, April/May, 2023	No Change
v.	Fifth Semester Examination, December, 2023	No Change
vi.	Sixth Semester Examination, April/May, 2024	No Change
vii	Seventh Semester Examination, December, 2024	No Change

viii	Eighth Semester Examination, April/May, 2025	No Change

IVA. M.Sc. Bioscience (Animal Science):

i.	First Semester Examination, December, 2021	No Change
ii.	Second Semester Examination, April/May, 2022	No Change
iii.	Third Semester Examination, December, 2022	No Change
iv.	Fourth Semester Examination, April/May, 2023	Change [a]

(a) In the fourth semester, the course "ZOO 516 Biology of Chordates and Histology" is proposed to be modified.

The modifications are done in the contents of Section-A of the syllabus. The topic "general organization and affinities of ostracoderms and placoderms" is replaced by Characteristic features of ostracoderms and placoderms as organization word here is confusing about their detailed description which is quite related to fossil records as these are the extinct groups and their affinities are more important.

The modification suggested amounts to less than 25% change, thus, the existing course code may be continued

The modified syllabus is included and marked as **Appendix-I** (Pages 1-3) and is proposed to be implemented for the students admitted in the Session 2021-22.

IVB. M.Sc. Bioscience (Plant Science):

i.	First Semester Examination, December, 2021	No Change
ii.	Second Semester Examination, April/May, 2022	No Change
iii.	Third Semester Examination, December, 2022	Change[a]
iv.	Fourth Semester Examination, April/May, 2023	Change[b]

(a) In the third semester, the course "BOT 519Phycology, Mycology and Lichenology" is proposed renamed "BOT 529 Phycology, Mycology and Plant Pathology". The syllabus modifications include updating and shifting the contents of the Phycology from Section-B to Section-A and similarly the contents of the Mycology are proposed to be shifted from the Section-A to Section-B in order to maintain the correct sequence of the topics to be studied. The Lichenology portion is proposed to be removed and required component incorporated in Section A. Plant Pathology has been shifted from IV Sm to the III Sm as it is in appropriate after the Mycology section in this course.

The course "BOT 517 Bryophyta, Pteridophyta and Gymnosperms" is proposed renamed "BOT 524 Bryophyta and Pteridophyta" as the present course is very lengthy and cannot be taught in much depth as required for a PG course. The portion on 'Gymnosperms' is proposed to be incorporated in a proposed new course in the fourth semester, "BOT 527 Gymnosperms, Paleobotany and Palynology".

The laboratory course “BOT 522L: Plant Science Lab-I: is proposed to be modified by introduction of the relevant experiments of the courses modified as above.

(b) In the fourth semester, the course "BOT 512 Angiosperms" is proposed to be discontinued and in its place a new course "BOT 528 Morphology, Anatomy and Taxonomy of Angiosperms" proposed to be introduced. Morphology and anatomy are core courses of plant sciences and would enrich the syllabus.

The course "BOT 507 Plant Pathology" is proposed to be shifted to the third semester and merged with phycology and mycology as “BOT 529 Phycology, Mycology and Plant Pathology”.

The course "BOT 527 Gymnosperms, Paleobotany and Palynology" is proposed to be introduced in the fourth semester.

The laboratory course “BOT 523L: Plant Science Lab-II: is proposed to be modified by introduction of the relevant experiments of the courses modified as above.

The modified syllabus is included and marked as **Appendix-II** (Pages 4-76)and is proposed to be implemented for the students admitted in the Session 2021-22.

IVC. M.Sc. Applied Microbiology and Biotechnology:

i.	First Semester Examination, December, 2021	No Change
ii.	Second Semester Examination, April/May, 2022	No Change
iii.	Third Semester Examination, December, 2022	No Change
iv.	Fourth Semester Examination, April/May, 2023	No Change

IVD. M.Sc. Biotechnology:

i.	First Semester Examination, December, 2021	No Change
ii.	Second Semester Examination, April/May, 2022	No Change
iii.	Third Semester Examination, December, 2022	No Change
iv.	Fourth Semester Examination, April/May, 2023	No Change

IVE. M.Sc. Bioinformatics:

i.	First Semester Examination, December, 2021	Change [a]
ii.	Second Semester Examination, April/May, 2022	Change [b]
iii.	Third Semester Examination, December, 2022	Change [c]
iv.	Fourth Semester Examination, April/May, 2023	No Change

(a) In the first semester, the course "BIO 426 Structural Biology" is proposed to be discontinued. This course is proposed to be introduced in second semester as “Biophysics and Structural Bioinformatics” including some biophysical principles regarding bio-macromolecular structure.

A new course “Biochemistry” is proposed to be introduced in the first semester offered common with the “BIO 418 Biochemistry” course being offered at M.Sc. Biotechnology/ AMBT/ Bioscience.

The course "CS 443 Fundamentals of Computer and Programming" has been updated in section C (programming with MATLAB has been replaced with C programming).

"CS 443L Fundamentals of Computer and Programming Lab" is proposed to be discontinued, and some contents of this course has been merged with the course "*In Silico* Laboratory – I".

The course "MATH 421 Introductory Mathematics" is proposed to be updated with “Mathematics and Statistics-I” including concepts of algebra and probability distribution.

"BIN 406 Biological Databases" is proposed to be replaced with a new course “Biological databases and Management systems” including the concepts of DBMS.

The course BIO 419L Bioscience Lab-I is proposed to be discontinued. A revised syllabus of core Bioinformatics of six credit practical course “*In Silico* Laboratory – I (C programming, Biol. Databases and DBMS)” is proposed to be introduced.

(b) In the second semester, relevant modifications in the course "BIN 404 Algorithms in Computational Biology "is proposed.

The course "BIN 407 Sequence analysis and Phylogeny" is proposed to be updated and some repeated and irrelevant terms are removed.

No change is proposed in the contents of "CS 446 Programming with Perl and R", but the credit will be reduced to TWO.

A new course “Mathematics and Statistics II” is proposed to be introduced which includes discrete mathematics and statistical theorems.

Two more new courses on core Bioinformatics are proposed to introduced, "Omics Bioinformatics" and "Biophysics and Structural Bioinformatics".

The courses "BT 408Genetic Engineering" (c.w.- MSc, AMBT, BT, Biosci II Sem), "CS 418 Database Management System" and "CS 446L Programming with Perl and R Lab" are proposed to be discontinued and the contents are merged with other courses.

A six-credit practical course “*In Silico* Laboratory – II (Perl and R, SQAP, BSB, NGS)” is proposed to be introduced.

(c) In the third semester, the course "BIN 511 Biomolecular Modeling and Computational Drug Design" is proposed discontinued and the course “Biomolecular Modeling and Simulation” introduced by modifying and updating the contents. The application part of computer aided drug designing has been taken to develop an elective course.

The course "BT 545 Genomics and Proteomics" is proposed to be discontinued. Appropriate contents have been incorporated in a new course proposed to be named as "Omics Bioinformatics." in the second semester.

The existing course "CS 538 Python Programming" has been revised to fulfill the requirements of non-programming background students in Biosciences and Bioinformatics.

The "CS 538L Python Programming Lab" course is proposed to discontinue and appropriate contents have been incorporated in the course "*In Silico* Laboratory – III".

A new course "Network and Systems Biology" is proposed to be introduced. The elective course "Systems Biology" is proposed to be discontinued as elective, however, considering its importance in core Bioinformatics the contents are proposed to be merged and introduced as a proposed new core course "Biophysics and Structural Bioinformatics" in the second semester.

A list of open and discipline electives are proposed from which the students can opt each of them in Semester III with prior permission of respective heads and time table permitting.

From the existing list of electives, the course "BIN 513 Systems Biology" is proposed to be discontinued. The course "BIN 514 RNA Structure Function and Transcriptomics" is proposed to be updated as "RNA Bioinformatics" including the applications of coding and non-coding RNAs in biology.

A new elective course "Computational Drug Discovery" is proposed to be introduced. The rest of the elective courses remain unchanged.

The laboratory course "BIN 511L Biomolecular Modeling and Computational Drug Design Lab" is proposed to be discontinued and appropriate contents have been incorporated in "In Silico Laboratory – III".

A six-credit practical course "*In Silico* Laboratory – III (Python programming, BMS, CADD)" is proposed to be introduced.

E-resources have been proposed for the theory courses and the list of recommended books has been updated. All modifications have been done to suit the current requirements of various preparative exams and enhance the knowledge and skill component.

In **fourth semester**, there will be dissertation and one reading elective. The pattern and list of reading electives is proposed to remain unaltered.

The modified syllabus is included and marked as **Appendix-III** (Pages 77-152) and is proposed to be implemented from the session 2021-22 for the newly admitted students

V. M. Tech. Biotechnology

i.	First Semester Examination, December, 2021	No Change
ii.	Second Semester Examination, April/May, 2022	No Change
iii.	Third Semester Examination, December, 2022	No Change
iv.	Fourth Semester Examination, April/May, 2023	No Change

VI.Certificate Examination:

i.**Molecular Modeling and Drug Designing:**

The members discussed the syllabus of the "Certificate Course in Molecular Modeling and Drug Designing" and found it to be adequate.

VII.Diploma Examination:

i. **Diploma in Computational Biology**:

The members discussed the syllabus of the "Diploma in Computational Biology" and found it to be adequate. No modifications are suggested.

ii. **PG Diploma/ Diploma in Bioinformatics**:

The Convener apprised the Board the PG Diploma course has been previously running in the department and was of one year duration. According to the UGC (Open and Distance Learning Programmes and Online Programmes) Regulations, 2020, PG Diploma courses would have to be of 2 years duration. It was proposed that since the department was already running a M.Sc. course in Bioinformatics, a 2 year PG Diploma would not be advisable.

The Board recommends that a 2 year PG Diploma may not be introduced.

4. The Programme Educational Objective and Programme Outcome of all the UG and PG programmes currently running in the department were thoroughly reviewed by the members of the BOS and found it to be adequate. The Learning Outcomes of all the courses running in semesters were reviewed and found it to be adequate.

5. The Convener informed the Board that there were no suitable alternate online add-on courses for the programmes viz., B.Tech. Biotechnology, M.Sc. Bioscience (Animal Science), M.Sc. Bioscience (Plant Science), M.Sc. Applied Microbiology and Biotechnology, M.Sc. Biotechnology and M.Tech. Biotechnology. It was recommended the Department undertake further exercise from time to time and if any such courses are found it may be considered in future.

6. The Board noted the MoU with the Merck Innovation Labs, Bangalore; Bioxenclue Private Limited, UP and other reputed content providers/ companies for conducting joint workshops and training programmes/ courses and recommended that they be considered for implementation as per the Rules of the Vidyapith on due approval.

7. The Board noted the Curriculum for the courses running in the other programmes of the Vidyapith. The courses which are proposed to be modified/updated/discontinued are reviewed under point number 3 above.

8. In view of the note of the Vice-Chancellor regarding the standard of the question papers, the Board examined the question papers of periodical test and semester examinations of the session 2019-2020.

The question papers were thoroughly studied by the various subject teachers and it was observed that quality of question papers has not deteriorated in the session 2019-20 vis-à-vis the previous years. At UG level, on an average, more than 80% questions belong to either High (Excellent) or Medium (Good) category. Similarly, at PG level too, the results are nearly same.

The analysis of the question papers summarized in **Appendix IVA** (page 153) for periodical examinations and **Appendix IVB** (page 154) for semester examinations and details given in various tables and figures in **Appendix IVC** (page 155- 160) for UG periodical examinations, **Appendix IVD** (page 161-166) for UG semester examinations, **Appendix IVE** (page 167-170) for PG periodical examinations and **Appendix IVF** (page 162-165) for PG semester examinations.

9. The roadmap, progress and glimpse of the achievement of the department were presented by the Convener and it was found satisfactory by the board. Some valuable suggestions for the extension of academic and research activities were given by the members.

10. The Convenor apprised the members that the curriculum of the M.Sc. Bioscience (Plant Science) and M.Sc. Bioscience (Animal Science) had been suitable modified and is similar to the M.Sc. Botany and M.Sc. Zoology programmes running at different universities all over India. The Convener apprised the members that the Vidyapith needed to issue equivalence certificates to the students for eligibility requirements in Government institutions. In the last few years, many students do not take admission to the M.Sc. Bioscience course due to the ambiguity of the programme nomenclature. The Board recommends the renaming of the M.Sc. Bioscience (Plant Science) and M.Sc. Bioscience (Animal Science) programme to the M.Sc. Botany and M.Sc. Zoology programmes respectively.

The meeting ended with vote of thanks.

Dy. Registrar
Banasthali Vidyapith
(Rajasthan)

Appendix-I

Department of Bioscience and Biotechnology
Banasthali Vidyapith

Table 1: Detail of the courses proposed to be modified in the fourth semester of M.Sc. Bioscience (Animal Science), proposed to be implemented for the students admitted in the Session 2021-22

Program name, Semester	**Course code and name**	**Learning Outcomes**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
M.Sc. Bioscience (Animal Science) IV semester	ZOO 516 Biology of Chordates and Histology	After successful completion of the course, students will be able to: • Identify and classify the major groups of organisms belonging to chordate phylum. • Compare and contrast the characteristics of fishes, amphibians, reptiles, birds, and mammals. • •Describe the histological techniques and basic structure of different tissues.	**Section A** Modern interpretation of origin of early chordates. Characteristic features and affinities of urochordata and cephalochordata. Transition from agnatha to gnathostomes. Fish: Origin and classification up to order, ~~general organization~~ andaffinities of ostracoderms and placoderms, general organization of ~~elasmobranchii,~~holocephali, ~~crossopterygii,~~dipnoi. Amphibia: Origin and classification up to order, general organization of amphibia, adaptive radiation, parental care. **Section B** Reptiles: Origin and classification up to order; general organization and affinities of chelonia, rhynococephalia, squamata, crocodalia, dinosaurs, venom in ophidians. Birds: Origin and classification up to order, origin of flight, flight adaptations, flightless birds. Mammals: Origin and classification up to order, characteristic features of prototheria and metatheria, adaptive radiation.	**Section A** Modern interpretation of origin of early chordates.Characteristic features and affinities of urochordata and cephalochordata. Transition from agnatha to gnathostomes. Fish: Origin and classification up to order, characteristic features and affinities of ostracoderms, and placoderms, general organization of chondrichtyes and osteichtyes and affinities of holocephalianddipoi Amphibia: Origin and classification up to order, general organization of amphibia, adaptive radiation, parental care. **Section B** Reptiles: Origin and classification up to order; general organization and affinities of chelonia, rhynococephalia, squamata, crocodalia, dinosaurs, venom in ophidians. Birds: Origin and classification up to order, origin of flight, flight adaptations, flightless birds. Mammals: Origin and classification up to order,	General characters of ostracoderms and placoderms are sufficient as organization word here is confusing about their detailed description which is quite related to fossil records as these are the extinct groups and their affinities are more important. Affinities of holocephali and dipnoi are needed as

Program name, Semester	Course code and name	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remarks
			Section C Introduction to histology, methods for the study of histology and observation of living and killed tissue. Epithelial tissue: Classification, special structural features, and specialization of free surface epithelia. Connective tissue: General types and special, properties of connective tissue with special reference to cartilage and bone. Muscular tissue: Structure of different types of muscular tissue (Skeletal, Cardiac & Smooth muscles). **Suggested Books:** ➢ Bloom, W. & Fawcett, D.W. A Textbook of histology (10th ed.). Philadelphia, USA: W.B. Saunders Company. ➢ Hildebrand, (1995). Analysis of vertebrate structure (4th ed.). NewJersey, USA: John Wiley. ➢ Junqueira, L.C. & Carneiro, J. (2005). Basic histology: Text and Atlas (11th ed.). New York, USA: McGraw Hill Medical. ➢ Parker, T.J. & Haswell, W.A (1978). Text book of zoology, Vol II.,Vertebrates. London, UK: Macmillan co. ➢ Pugh, F.H., Heiser, J.B., McFarland, W.N. (1979). Vertebrate life (4thed.). London, UK: Macmillan Publishing. ➢ Rej, S.K. (2015). General concepts of histology & endocrinology. Kolkata, India: New Central Book Agency. ➢ Young, (1981). The life of vertebrates (3rd ed.).	characteristic features of prototheria and metatheria, adaptive radiation. **Section C** Introduction to histology, methods for the study of histology and observation of living and killed tissue. Epithelial tissue: Classification, special structural features, and specialization of free surface epithelia. Connective tissue: General types and special, properties of connective tissue with special reference to cartilage and bone. Muscular tissue: Structure of different types of muscular tissue (Skeletal, Cardiac & Smooth muscles). **Suggested Books:** ➢ Bloom, W. & Fawcett, D.W. A Textbook of histology (10th ed.). Philadelphia, USA: W.B. Saunders Company. ➢ Hildebrand, (1995). Analysis of vertebrate structure (4th ed.). NewJersey, USA: John Wiley. ➢ Junqueira, L.C. & Carneiro, J. (2005). Basic histology: Text and Atlas (11th ed.). New York, USA: McGraw Hill Medical. ➢ Parker, T.J. & Haswell, W.A (1978). Text book of zoology, Vol II.,Vertebrates. London, UK: Macmillan co. ➢ Pugh, F.H., Heiser, J.B., McFarland, W.N. (1979). Vertebrate life (4thed.). London, UK: Macmillan Publishing. ➢ Rej, S.K. (2015). General concepts of histology &	details about fishes fall in in chondrichtyes (elasmobranchii) and osteichtyes (crosopterygii)

Program name, Semester	Course code and name	Learning Outcomes	Existing Syllabus	Suggested Syllabus	Remarks
			Oxford, UK: Oxford University Press. **Suggested e-Resources:** ➢ Mammals ➢ https://courses.lumenlearning.com/boundless-biology/chapter/mammals/ ➢ Birds ➢ https://courses.lumenlearning.com/boundless-biology/chapter/birds/ ➢ Methods for the study of histology ➢ https://www.microscopemaster.com/histochemistry.html ➢ Epithelial tissue and Connective tissue ➢ www.academia.edu/25115428/Histology_of_animal_tissue ➢ Muscular tissue http://medcell.med.yale.edu/histology/muscle_lab.php	endocrinology. Kolkata, India: New Central Book Agency. ➢ Young, (1981). The life of vertebrates (3rd ed.). Oxford, UK: Oxford University Press. **Suggested e-Resources:** ➢ Mammals ➢ https://courses.lumenlearning.com/boundless-biology/chapter/mammals/ ➢ Birds ➢ https://courses.lumenlearning.com/boundless-biology/chapter/birds/ ➢ Methods for the study of histology ➢ https://www.microscopemaster.com/histochemistry.html ➢ Epithelial tissue and Connective tissue ➢ www.academia.edu/25115428/Histology_of_animal_tissue ➢ Muscular tissue http://medcell.med.yale.edu/histology/muscle_lab.php	

* Matter in contrast (black background & white letters) is shifted to some other units, and material brought as a result of shift is also in contrast
# Matter in square brackets, bold, italic and crossed is deleted.
@ Proposed added materials are shaded in grey.

Department of Bioscience and Biotechnology, Banasthali Vidyapith
M.Sc. Bioscience (Plant Science) Programme I-II Semester

Existing Courses					
M.Sc. Bioscience (Plant Science) Sem. I		**L**	**T**	**P**	**C**
BIO 407	Cell and Molecular Biology	4	0	0	4
BIO 418	Biochemistry	4	0	0	4
BIO 425	Microbiology	4	0	0	4
BIN 425	Bioinformatics	4	0	0	4
BIO 401	Analytical Techniques-I	4	0	0	4
BIO 419L	Bioscience Lab-I	0	0	12	6
	Total	**20**	**0**	**12**	**26**

Proposed Courses					
M.Sc. Bioscience (Plant Science) Sem. I		**L**	**T**	**P**	**C**
BIO 407	Cell and Molecular Biology	4	0	0	4
BIO 418	Biochemistry	4	0	0	4
BIO 425	Microbiology	4	0	0	4
BIN 425	Bioinformatics	4	0	0	4
BIO 401	Analytical Techniques-I	4	0	0	4
BIO 419L	Bioscience Lab-I	0	0	12	6
	Total	**20**	**0**	**12**	**26**

Existing Courses					
M.Sc. Bioscience (Plant Science) Sem. II		**L**	**T**	**P**	**C**
BIO 406	Biostatistics and Research Methodology	4	0	0	4
BIO 410	Genetics	4	0	0	4
BIO 411	Immunology	4	0	0	4
BIO 422	Environmental Biology and Biotechnology	4	0	0	4
BT 408	Genetic Engineering	4	0	0	4
BIO 420L	Bioscience Lab-II	0	0	12	6
	Total	**20**	**0**	**12**	**26**

Proposed Courses					
M.Sc. Bioscience (Plant Science) Sem. II		**L**	**T**	**P**	**C**
BIO 406	Biostatistics and Research Methodology	4	0	0	4
BIO 410	Genetics	4	0	0	4
BIO 411	Immunology	4	0	0	4
BIO 422	Environmental Biology and Biotechnology	4	0	0	4
BT 408	Genetic Engineering	4	0	0	4
BIO 420L	Bioscience Lab-II	0	0	12	6
	Total	**20**	**0**	**12**	**26**

Department of Bioscience and Biotechnology, Banasthali Vidyapith
M.Sc. Bioscience (Plant Science) Programme III -IV Semester

Existing Courses					
M.Sc. Bioscience (Plant Science) Sem. III		**L**	**T**	**P**	**C**
BIO 519	Phycology, Mycology and ~~Lichenology~~	4	0	0	4
BOT 517	Bryophyta, Pteridophyta and Gymnosperms	4	0	0	4
BT 507	Cell and Tissue Culture Technology	4	0	0	4
BOT 518D	Literature Dissertation	0	0	8	4
BOT 522L	Plant Science Lab-I	0	0	12	6
	Discipline Elective	4	0	0	4
	Total	**16**	**0**	**20**	**26**

Proposed Courses					
M.Sc. Bioscience (Plant Science) Sem. III		**L**	**T**	**P**	**C**
BOT 529	Phycology, Mycology and Plant Pathology	4	0	0	4
BOT 524	Bryophyta and Pteridophyta	4	0	0	4
BT 507	Cell and Tissue Culture Technology	4	0	0	4
BOT 518D	Literature Dissertation	0	0	8	4
BOT 530L	Plant Science Lab-I	0	0	12	6
	Discipline Elective	4	0	0	4
	Total	**16**	**0**	**20**	**26**

Existing Courses					
M.Sc. Bioscience (Plant Science) Sem. IV		**L**	**T**	**P**	**C**
BOT 512	Angiosperms	4	0	0	4
BOT 504	Cytogenetics and Plant Breeding	4	0	0	4
BOT 508	Plant Physiology	4	0	0	4
	Alternate online core course Plant Physiology and Taxonomy https://www.acs.edu.au/courses/botany-i-plant-physiology-and-taxonomy-199.aspx				
BOT 507	Plant Pathology	4	0	0	4
BOT 523L	Plant Science Lab-II	0	0	12	6
	Open Elective	4	0	0	4
	Reading Elective-I&II	0	0	0	2
	Total	**20**	**0**	**12**	**28**

Proposed Courses					
M.Sc. Bioscience (Plant Science) Sem. IV		**L**	**T**	**P**	**C**
BOT 528	Morphology, Anatomy and Taxonomy of Angiosperms	4	0	0	4
BOT 504	Cytogenetics and Plant Breeding	4	0	0	4
BOT 508	Plant Physiology	4	0	0	4
	Alternate online core course Plant Physiology and Taxonomy https://www.acs.edu.au/courses/botany-i-plant-physiology-and-taxonomy-199.aspx				
BOT 527	Gymnosperms, Paleobotany and Palynology	4	0	0	4
BOT 531L	Plant Science Lab-II	0	0	12	6
	Open Elective	4	0	0	4
	Reading Elective-I&II	0	0	0	2
	Total	**20**	**0**	**12**	**28**

List of Elective courses to be offered in third and fourth semester							Proposed List of Elective courses to be offered in third and fourth semester						
BOT 520	Phycology-I	4	0	0	4		BOT 520	Phycology-I	4	0	0	4
BOT 515	Bryology-I	4	0	0	4		BOT 515	Bryology-I	4	0	0	4
BOT 513	Angiosperms Taxonomy and Systematics-I	4	0	0	4		BOT 513	Angiosperms Taxonomy and Systematics-I	4	0	0	4
BT 521	Plant Biotechnology	4	0	0	4		BT 521	Plant Biotechnology	4	0	0	4
PHY 532	Biophysics-I	4	0	0	4		PHY 532	Biophysics-I	4	0	0	4
ENVS 402	Ecology and Environment	4	0	0	4		ENVS 402	Ecology and Environment	4	0	0	4
	Fundamentals of Ecology for Sustainable Ecosystem https://www.extension.harvard.edu/academics/courses/fundamentals-ecology/12779	4	0	0	4			Fundamentals of Ecology for Sustainable Ecosystem https://www.extension.harvard.edu/academics/courses/fundamentals-ecology/12779	4	0	0	4
BOT 521	Phycology-II	4	0	0	4		BOT 521	Phycology-II	4	0	0	4
BOT 516	Bryology-II	4	0	0	4		BOT 516	Bryology-II	4	0	0	4
BOT 514	Angiosperms Taxonomy and Systematics-II	4	0	0	4		BOT 514	Angiosperms Taxonomy and Systematics-II	4	0	0	4
BT 524	Advanced Plant Biotechnology	4	0	0	4		BT 524	Advanced Plant Biotechnology	4	0	0	4
PHY 533	Biophysics-II	4	0	0	4		PHY533	Biophysics-II	4	0	0	4
ENVS 502	Biodiversity and Conservation	4	0	0	4		ENVS 502	Biodiversity and Conservation	4	0	0	4
List of Reading Elective courses to be offered in fourth semester							**Proposed List of Reading Elective courses to be offered in fourth semester**						
BT 529R	Drug Discovery	0	0	4	2		BT 529R	Drug Discovery	0	0	4	2
BT 531R	Human Genetics and Diseases	0	0	4	2		BT 531R	Human Genetics and Diseases	0	0	4	2
BT 534R	Intellectual Property Rights	0	0	4	2		BT 534R	Intellectual Property Rights	0	0	4	2
BT 535R	Medical Microbiology	0	0	4	2		BT 535R	Medical Microbiology	0	0	4	2
BT 538R	Molecular Plant Breeding	0	0	4	2		BT 538R	Molecular Plant Breeding	0	0	4	2
BT 539R	Protein Engineering	0	0	4	2		BT 539R	Protein Engineering	0	0	4	2
	Bio- organic Chemistry: http://nptel.ac.in/courses/104103018/#							Bio- organic Chemistry: https://nptel.ac.in/courses/104/103/104103018/				
	Enzyme Science and Engineering http://freevideolectures.com/Course/85/Enzyme-Science-and-Engineering/1							Enzyme Science and Engineering https://nptel.ac.in/courses/102/102/102102033/				
	Biocatalysis in organic synthesis: http://nptel.ac.in/courses/104105032/							Biocatalysis in organic synthesis: https://nptel.ac.in/courses/104/105/104105032/				
	Comprehensive Disaster Risk Management Framework							Comprehensive Disaster Risk Management Framework: https://nidm.gov.in/PDF/IEC/online_new.pdf				

	www.nidm.gov.in/online.asp							www.nidm.gov.in/online.asp				
	General Course on Intellectual Property: https://welc.wipo.int/acc/index.jsf?page=courseCatalog.xhtml							General Course on Intellectual Property: https://welc.wipo.int/acc/index.jsf?page=courseCatalog.xhtml				
	Environmental Management - An Introduction: www.algonquincollege.com/ ccol/courses/environmental-management-an-introduction/							Environmental Management - An Introduction: www.algonquincollege.com/ ccol/courses/environmental-management-anintroduction				

[*] Matter in contrast (black background & white letters) is shifted to some other units, and material brought as a result of shift is also in contrast.
[#] Matter in square brackets, bold, italic and crossed is deleted.
[@] Proposed added materials are shaded in grey.

Comparative Table: M.Sc. Bioscience (Plant Science) III Semester: Existing and Modified syllabus, Suggested Books and Suggested E-Resources

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
M.Sc. Bioscience (Plant Science) I Semester					
1.	-	-	-	-	No change in the existing syllabus
M.Sc. Bioscience (Plant Science) II Semester					
2.	-	-	-	-	No change in the existing syllabus
M.Sc. Bioscience (Plant Science) III Semester					
3.	BOT 519: Phycology, Mycology and Lichenology	After successful completion of the course, students should be able to: • Acquire the knowledge related to various life forms, ecological and economical importance of these plant groups. • identify these interesting forms in their surroundings and will convey the importance to the community which will help in the conservation of these forms to get better ecosystem.	BOT ~~519~~: Phycology, Mycology ~~and Lichenology~~ **Section B** • ~~Algae general characters~~, ~~definitions and scope. Comparative survey of important systems of classification of algae, criteria for algal classification and modern trends. Diagnostic features of algal phyla: range of thallus and reproductive diversity.~~ Life history patterns: ~~parallelism in evolution.~~ • ~~Comparative account of algal pigments; light microscopic structure, ultra structure, function and importance of cell wall, flagella chloroplasts pyrenoids eyespots, nucleus, contractile vacuole and their importance in taxonomy.~~ • ~~Study of Cyanophyta (*Microcystis*, *Stigonema*), Prochlorophyta (*Prochloron*), Chlorophyta (*Chlorella Hydrodictyon*, *Nitella*) Xanthophyta (*Botrydium*), Bacillariophyta (*Navicula*), Phaeophyta (*Dictyota*)~~	**BOT 529: Phycology, Mycology and Plant Pathology** **Section A - Phycology** • General characteristics of algae, habitat diversity, • Endosymbiosis theory and its significance, range of thallus structure and reproductive diversity. study of algal pigments; cell wall, flagella, reserve food and modes of reproduction • Important systems of classification of algae, criteria for algal classification and modern trends. Brief Life cycle patterns. • Cyanophyta - general features and ecology, study the genera - *Microcystis*, *Lyngbya* and *Scytonema*. • Glaucophyta - general features, study the genera – *Glaucocystis.* • Chlorophyta - characteristic features of different classes highlighting distinctive features of different orders, study the genera	The syllabus has been revised. The Lichenology portion is removed and required component incorporated in Section A. Section A and Section B have been interchanges as Phycology should be studied before Mycology. Plant Pathology has been shifted from III Sm to the Ist Sm as it is in appropriate after the Mycology section in this course.

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
			• ~~Algae in biotechnology.~~ • Economic importance of algae. **Section-A** • ~~Introduction, scope and general principles~~ of classification of fungi. • Myxomycotina: Plasmodiophorales. • Mastigomycotina: Chytridiales, Blastocladiales, Saprolegniales and Peronosporales. • Zygomycotina: Mucorales and Entomophthorales. • Ascomycotina: Endomycetales, Protomycetales, Taphrinales, Erysiphales, Eurotiales, Sphaeriales, Helotiales, Phacidiales and Pezizales. • Basidiomycotina: Uredinales, Ustilaginales, Lycoperdales, Nidulariales, Sclerodermatales, Phallales, Agaricales, Aphyllophorales, Tremellales and Auriculariales. • Deuteromycotina: Sphaeropsidales, Melanconiales, Moniliales and Mycelia sterilia.	*Chlamydomonas*, *Oedogonium*, *Spirogyra*, and *Chara*. • Rhodophyta - general features; specialties in sexual reproduction and post-fertilization changes, study the genera -*Polysiphonia*. • Euglenophyta - general features and ecology, study the genera – *Euglena*. • Heterokontophyta: Xanthophyceae - general features, study the genera - *Vaucheria*; Bacillariophycece - general Features and ecology; Phaeophyceae - general features and ecology, life cycle patterns, *Ectocarpus* and *Fucus*. • Economic importance of Algae. **Section-B - Mycology** • Classification of fungi. • Life cycle patterns: basic pattern of sexuality, sexual mechanisms and their correlations in different groups of fungi, parasexual cycle and its significance. • Myxomycotina - basic features and special significance, Plasmodiophorales. • Mastigomycotina - basic features and special significance, Chytridiales, Blastocladiales, Saprolegniales and Peronosporales. • Zygomycotina - basic features and pattern of sexuality, Mucorales and Entomophthorales. • Ascomycotina - types of ascocarps, methods of ascospore discharge, Endomycetales, Protomycetales, Taphrinales, Erysiphales,	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
			Section C • ~~A general account of Lichens and its symbionts, thallus structure, reproduction, physiology, classification and distribution, Chemistry of Lichens, Isolation of symbionts and synthesis of thallus, Economic importance.~~ • ~~Study types: *Dermatocarpon*, *Parmelia*, *Heterodermia*.~~ **Suggested Books:** ➢ Alexopoulus, C.J., Mims. C.W. & Blackwel, M. (1996). *Introductory Mycology*. John Wiley & Sons Ind. ➢ Kumar, H.D. & Singh, H.N. (1979). *A Textbook On Algae*. Macmillan Publishers Limited. ➢ Mehrotra, R.S. & Aneja, R.S. (1998). *An Introduction to Mycology*.New Age Intermediate	Eurotiales, Sphaeriales, Helotiales, Phacidiales and Pezizales. • Basidiomycotina - fruiting structures of the members and methods of basidiospore discharge, Uredinales, Ustilaginales, Lycoperdales, Nidulariales, Sclerodermatales, Phallales,Agaricales, Aphyllophorales, Tremellales and Auriculariales. • Deuteromycotina A general account of the asexual fruit bodies and sporulating structures, classification with special reference to conidial ontogeny, Sphaeropsidales, Melanconiales, Moniliales and Mycelia sterilia. • Economic importance of Fungi. **Section C- Plant pathology** • History and the development of Plant Pathology, Plant diseases - Basic concept and Classification of plant diseases. • Pathogenesis: Contact, entry and penetration, establishment of the plant pathogens inside the host plant. Genetic variability of plant pathogens. • Host plant in defense: Plant defense responses - structural and biochemical defense and host plant resistance -horizontal and vertical resistance-basic concept. Genetic basis of host pathogen interactions, its role in specificity of plant disease. • Plant disease epidemiology: Factors responsible for development of plant disease	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
			Press. ➢ Morris, I.(1986). *An Introduction to the Algae*. Cambridge University Press, U.K. ➢ Nash, T.H. 2011. *Lichen Biology*. Cambridge University Press. ➢ Round, F.E. (1986). *The Biology of Algae*. Cambridge University Press, Cambridge. **Suggested e-Resources**: ➢ **Lichen: General account** https://www.anbg.gov.au/lichen/what-is-lichen.html ➢ **Introduction to Lichen** https://www.nybg.org/bsci/lichens/ ➢ **Algae: General account** https://www.livescience.com/54979-what-are-algae.html ➢ **Classification, Economic Uses of Algae** https://naturalhistory.si.edu/research/botany ➢ **Fungi: General account** https://microbiologyonline.org/about-microbiology/introducing-microbes/fungi ➢ **Fungal Biology** https://www.highveld.com/microbiology/what-are-fungi.html	epidemic; Disease forecasting and Remote Sensing. • Basic idea about the Molecular method for detection of plant pathogen. • Strategies of plant disease management: Cultural, Chemical, biological and integrated management of Plant diseases; Biopesticides.. • Epiphytotics: Compound and simple interest diseases, mathematical model, essential condition and analysis. • Study of plant diseases: Symptoms, etiology, disease cycles and control measures of some important diseases of the following plants: - Fungal diseases of cereals and millets: Rusts of wheat, Loose and covered smut of wheat and Barley, fungal diseases of Bajra, Charcoal rot of Maize. Fungal diseases of vegetables and fruits: Early blight of Potato, Wart disease of Potato, Powdery mildew of Cucurbits & Pea, Die back of Chillies, Tikka disease of Groundnut, Wilt & root rot of Gram, Red rot and smut of Sugarcane. - Bacterial diseases: Red stripe of sugarcane, Angular leaf spot of cotton, Soft rot of vegetables. - Viral diseases: Leaf roll of potato & tomato, Mosaic disease of tomato. - Mycoplasma diseases: Sandal spike,	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
				Sesamum phyllody, Little leaf of Brinjal. - Nematode diseases: Root knot of vegetable (Cucumber), Molya disease of Wheat and Barley. - Insect diseases: General account of plant and animal galls with special reference to Mango and Ziziphus. **Suggested Books:** ➢ Lee, R. E. (2008). *Phycology*. Cambridge University Press, New York ➢ C.Vanden Hoek , D.G. Mann and H.M. Jahns (1995) . Algae- An introuction to phycology, Cambridge University Press, New York ➢ Graham L E , Graham JM, and Wilcox L W (2009). Algae , Pearson ➢ Bilgrami, K.S. & Saha, L. (2007). *A textbook of Algae*. CBS Publishers and Distributors. ➢ Round, F.E. (1986). *The Biology of Algae*. Cambridge University Press, Cambridge. ➢ Kumar, H.D., and Singh, H.N. (1979). *A textbook on Algae*. Macmillan Publishers Limited. ➢ Morris, I.(1986). *An Introduction to the Algae*. Cambridge University Press, U.K. ➢ Kumar, H.D. & Singh, H.N. (1979). *A Textbook On Algae*. Macmillan Publishers Limited ➢ Alexopoulus, C.J., Mims. C.W. & Blackwel, M. (1996). *Introductory Mycology*. John Wiley & Sons Ind. ➢ Mehrotra, R.S. & Aneja, R.S. (1998). *An*	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
				Introduction to Mycology.New Age Intermediate Press. ➢ Agrios, G.N. (2005). *Plant Pathology*. USA: Elsevier Publication. ➢ Alexopoulus, C.M. (1996). *Introductory Mycology*. New York: John Wiley and Sons. ➢ Bilgrami, K.S. & Dubey, H.C. (1998). *Text Book of Modern Pathology*. India: Vikas Publishing House Pvt. Ltd. ➢ Biswas, S. B. & Biswas, A. (2006) *An Introduction to Viruses*. India: Vikas Publishing House Pvt. Ltd. ➢ Butler, E.J. (1918). *Fungi and Diseases in Plants*. Kolkata: Thanker Spink and Co. ➢ Mehrotra, R.S. (1990). *Plant Pathology*. Tata McGraw Hill Publication Co. ➢ Mundkur, B. (1967). *Fungi and Plant Diseases*. Macmillan and Co. Limited ➢ Singh, R.S. (2017). *Plant Disease*. IBH, New Delhi: Oxford. **Suggested e-Resources**: ➢ **Algae: General account** https://www.livescience.com/54979-what-are-algae.html ➢ **Classification, Economic Uses of Algae** https://naturalhistory.si.edu/research/botany ➢ **Fungi: General account** https://microbiologyonline.org/about-microbiology/introducing-microbes/fungi ➢ **Fungal Biology** https://www.highveld.com/microbiology/what-	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
				are-fungi.html	
4.	**BOT 511** Bryophyta, Pteridophyta and Gymnosperm	After successful completion of the course, students should be able to: • Acquire the knowledge related to various cryptogamic life forms, ecological and economical importance of these two groups • identify these forms in their surroundings and will attract towards these branches of classical botany • understand the morphological diversity of cryptogams and evolutionary connections between Bryophytes and Pteridophytes • know why these plants have to conserve for the sustainable ecosystem • placed as researchers in research institutes and universities as these branches of botany eagerly searching for passionate young researchers	**BOT ~~511~~** Bryophyta, Pteridophyta ~~and Gymnosperm~~ **Section A** • ~~General characteristics of bryophytes, alternation~~ of generation and classification. Life-cycle of ~~bryophytes,~~ asexual and sexual reproduction in various groups. Ecology - habitat diversity, growth forms, growth factors. • Role of bryophytes in pollution monitoring, geobotanical prospecting, horticultural uses, economic importance. • Moss protonema, protonemal differentiation and bud induction. • Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders of: • Bryopsida: Sphagnales (*Sphagnum*), Andreaeales (*Andreaea*), Takakiales (*Takakia*), Buxbaumiales (*Buxbaumia*), Bryales (*Physcomitrium*), Polytrichales (*Polytrichum*). • Hepaticcopsida: Calobryales (*Calobryum*), Metzgeriales (*Metzgeria*), Jungermanniales (*Jungermannia*), Sphaerocarpales (*Sphaerocarpous*), Monocleales (*Monoclea*), Marchantiales (*Plagiochasma*, *Lunularia*, *Dumortiera*, *Cyathodium*). • Anthocerotopsida: Anthocerotaceae (*Anthoceros*, *Folioceros*), Notothyladaceae (*Notothylas*), Dendrocerotaceae (*Dendroceros*).	**Bryophyta and Pteridophyta** **Section A** • General characteristics of cryptogams, alternation of generation. • Life-cycle, asexual and sexual reproduction in various groups. • Ecology - habitat diversity, growth forms, growth factors. • Adaptive Strategies of cryptogams. • Biotechnology and cryptogams. **Section B** • General Charcteristics and Classification of bryophytes (ICN). • Role of bryophytes in pollution monitoring, geobotanical prospecting, horticultural uses, economic importance. • Bryological Interactions. • Moss protonema, protonemal differentiation and bud induction. • Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders of: – Bryopsida: Sphagnales (*Sphagnum*), Andreaeales (*Andreaea*), Takakiales (*Takakia*), Buxbaumiales (*Buxbaumia*), Bryales (*Physcomitrium*), Polytrichales (*Polytrichum*). – Hepaticopsida: Calobryales (*Calobryum*), Metzgeriales (*Metzgeria*), Jungermanniales	The syllabus has been updated. Gymnosperns is shifted to the 3rd Sem. The existing syllabus is very lengthy.

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
				(*Jungermannia*), Sphaerocarpales (*Sphaerocarpous*), Monocleales (*Monoclea*), Marchantiales (*Plagiochasma*, *Lunularia*, *Dumortiera*, *Cyathodium*). – Anthocerotopsida: Anthocerotaceae (*Anthoceros*, *Foliioceros*), Notothyladaceae (*Notothylas*), Dendrocerotaceae (*Dendroceros*).	
			Section B • General characteristics features and classification (Smith, 1955 and Bierhorst, 1971) of Pteridophytes. Morphology, anatomy and reproduction of Psilophyta (*Psilotum*), Lycophyta (*Lycopodium*, *Selaginella*), Sphenophyta (*Equisetum*), Pteropsida (*Marsilea*). • Telome theory, Classification and evolution of steles. Heterospory and origin of seed habit. Apogamy, Apospory and Alternation of generations. • General account of fossil vascular cryptogams: *Rhynia*, *Horneophyton*, *Asteroxylon*, *Calamites* and *Lepidodendron*. Origin of cryptogams. Evolution of sorus in ferns. Economic importance of Pteridophytes. **Section C** • General diagnostic features of gymnosperms with special reference to drop mechanism, vessel less and fruitless seed plants. General account of anatomical variations in gymnospermic leaves (*Abies*, *Cedrus*, *Picea*, *Cycas* and *Taxus*).	**Section C** • General characteristics and classification (Smith, 1955 and Bierhorst, 1971) of Pteridophytes. • Morphology, anatomy and reproduction of Psilophyta (*Psilotum*), Lycophyta (*Lycopodium*, *Selaginella*), Sphenophyta (*Equisetum*), Pteropsida (*Marsilea*). • Telome theory, Classification and evolution of steles. Heterospory and origin of seed habit. • Evolution of sorus in ferns. • Apogamy, Apospory and alternation of generations. • General account of fossil vascular cryptogams: *Rhynia*, *Horneophyton*, *Asteroxylon*, *Calamites* and *Lepidodendron*. Origin of cryptogams. • Economic Importance of Pteridophytes **Suggested Books:** ➢ Alam, A. (2015). *Textbook of Bryophyta*. New Delhi: I K International Publishers. ➢ Chopra, R.N. And Kumra, P.K. (2018). *Biology of Bryophytes*. New Age International	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
			• Outline classification of gymnosperms as proposed by Sporne (1965) and Sandra Holms (1986), distribution of gymnosperms with special reference to India. Economic importance of gymnosperms.A study of morphology, internal structure, outline life history of the following: • Cycadopsida: Medullosaceae *Medullosa*, Glossopteridaceae *Glossopteris*, Cycadeoideaceae - *Cycadeoidea* (*Bennittites*), Cycadaceae -*Cycas* • Coniferopsida: Ginkgoaceae – *Ginkgo*, Pinaceae – *Pinus* • Gnetopsida: Gnetales - *Gnetum*, Welwitschiales - *Welwitschia* **Suggested Books:** ➢ Alam, A. (2015). *Textbook of Bryophyta*. New Delhi: I K International Publishers. ➢ Bhatnagar, S.P. & Moitra, A. (1996). *Gymnosperm*. New Delhi: New Age International Pvt. Ltd. ➢ Parihar, N.S. (1996). *Biology and Morphology of Pteridophytes*. Allahabad: Central Book Depot. ➢ Singh, M. (1978). *Embryology of Gymnosperms, Encyclopaedia of Plant Anatomy*. Berlin: X. Gebruder Bortraeger. ➢ Sporne, K.K. (1991). *The morphology of pteridophytes*. Mumbai : B.I. Publishing Pvt. Ltd. ➢ Stewart, W.N & Rathwell, G.W. (1993). *Paleobotany and the evolution of plants*. Cambridge University press. ➢ Sunderrajan, S. (2007). *Introduction to*	Publishers, New Delhi. ➢ Parihar, N.S. (1996). *Biology and Morphology of Pteridophytes*. Allahabad: Central Book Depot. ➢ Sporne, K.K. (1991). *The morphology of pteridophytes*. Mumbai: B.I. Publishing Pvt. Ltd. ➢ Sunderrajan, S. (2007). *Introduction to pteridophyta*, New Delhi: New Age International Publishers. ➢ Glime, J.M. (2018). *Bryophyte Ecology Vol. 1*, Michigan Tech. USA. **Suggested e-Resources:** ➢ **Bryophytes: General account** http://bryophytes.plant.siu.edu/ ➢ **Bryophytes: Classification, structure** https://www.toppr.com/guides/biology/plant-kingdom/bryophytes/ ➢ **Bryophytes**: **Online lectures** https://www.swayamprabha.gov.in/index.php/program/ ➢ **Pteridophytes: General account, Classification, Life cycle** https://www.toppr.com/guides/biology/plant-kingdom/pteridophytes/	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
			pteridophyta, New Delhi: New Age International Publishers. **Suggested e-Resources:** ➢ **Bryophytes: General account** http://bryophytes.plant.siu.edu/ ➢ **Bryophytes: Classification, structure** https://www.toppr.com/guides/biology/plant-kingdom/bryophytes/ ➢ **Bryophytes**: **Online lectures** https://www.swayamprabha.gov.in/index.php/program/ ➢ **Pteridophytes: General account, Classification, Life cycle** https://www.toppr.com/guides/biology/plant-kingdom/pteridophytes/ ➢ **Gymnosperms: General account, Classification, Life cycle** https://www.thoughtco.com/what-are-gymnosperms-4164250 ➢ **Gymnosperms: Economic importance** https://www.toppr.com/guides/biology/plant-kingdom/gymnosperms/		
17.	**BT 507** Cell and Tissue Culture Technology	After successful completion of the course, students should be able to: • develop comprehensive concepts of cell and tissue culture techniques and methodology • understand use of various	**Section-A** • Historical background and terminologies used in cell & tissue culture. • Basic techniques of cell and tissue culture, sterilization, aseptic tissue transfer, concept of totipotency. • Nutritional requirement of cell in vitro, various types of nutrient media.	No change in the existing syllabus	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
		plant and animal tissue culture techniques • identify areas of applications of cell and tissue culture in research, agriculture, horticulture, medicine and pharmaceutical industries	• Contamination and cytotoxicity. • Cryopreservation and cell storage. • Isolation of plant cells, single cell cultures and cloning. **Section-B** • Organogenesis and somatic embryogenesis, applications in agriculture, horticulture & forestry. • Haploid production: androgenesis, gynogenesis: various techniques and applications. • Production of disease free plants by tissue culture methods. • Protoplast isolation and culture, fusion of protoplasts. • Somatic hybrids, selection methods, gene expression in somatic hybrids. **Section-C** • Disaggregation of animal tissue, isolation of cells, single cell culture, routine maintenance of animal cell lines. • Cloning & selection of specific animal cell types. • Transfection: gene transfer methods for adherent and non-adherent cell culture. • Cell fusion: fusogen, animal somatic cell fusion and selection of cybrids. • Animal organ culture. • Elementary idea about animal cell culture products. **Suggested Books:** ➢ Bhojwani, S.S. & Razdan, M.K. (1996). *Plant Tissue Culture*. USA: Elsevier Science.		

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
			➢ Buler, M. (2003). *Animal Cell Culture and Technology* (2nd ed.). UK: Taylor & Francis. ➢ Chawla, H.S. (2000). *Introduction to Plant Biotechnology*. US: Science Publishers. ➢ Clynes, M. (Ed.) (1998). *Animal Cell Culture Techniques*. Germany: Springer-Verlag Berlin Heidelberg. ➢ Davis, J.M. (2011). *Animal Cell Culture: Essential Methods*. New Jersey, USA: John Wiley & Sons Ltd. ➢ Freshney, R.I. (2011). *Culture of Animal Cells: A Manual of Basic Technique and Specialized Applications* (6thed.). USA: Wiley-Blackwell. ➢ John, R.W. (2000). *Animal Cell Culture: A Practical Approach* (3rd ed.). UK: Oxford University Press. ➢ Mathur, S. (2006). *Animal Cell and Tissue Culture*. India: Agrobios. ➢ Pollard**,** J.W. &Walker, J.M. (Eds.) (1990). *Animal Cell Culture*. USA: Humana Press ➢ Razdan, M.K. (2006). *Introduction to Plant Tissue Culture*. New Delhi, India: Oxford and IBH Pub. ➢ Smith, R.H (Ed.). (2013). *Plant tissue culture: Techniques and experiments*. Amsterdam: Academic Press. **Suggested e- Resources:** ➢ **Background of Tissue Culture Technology** http://www.biologydiscussion.com/botany/tissue-culture/tissue-culture-definition-history-and-importance/42944 ➢ **Embryogenesis and organogenesis**		

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
			https://nptel.ac.in/courses/102103016/module1/lec8/3.html ➢ **Single cell cultures and cloning** http://www.biologydiscussion.com/botany/tissue-culture/methods-for-obtaining-single-cell-clones-from-callus-culture-plant-tissue-culture/43004 ➢ **Protoplasm isolation and regeneration** https://nptel.ac.in/courses/102103016/12 ➢ **Haploid plant production** http://www.biologydiscussion.com/plants/haploid-plants/production-of-haploid-plants-with-diagram/10700 ➢ **Preservation of cell lines** https://www.ukessays.com/essays/biology/techniques-for-cell-preservation-biology-essay.php ➢ **Somatic hybridization** http://www.biologydiscussion.com/somatic-hybridization/somatic-hybridization-aspects-applications-and-limitations/10686 ➢ **Animal cell culture products** http://www.biologydiscussion.com/biotechnology/animal-biotechnology/applications-of-animal-cell-cultures/10457 ➢ **Cell Culture Technology** https://onlinecourses.nptel.ac.in/noc17_bt21/preview		
18.	**BOT 518D** Literature Dissertation	After successful completion of course students should be able to: • develop the competency in	-	No change in the existing pattern	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
		identifying the scientific problem • access the primary literatures, understand the scientific reports and extract the useful information from it • write a scientific document highlighting introduction of the research problem, review of literature, conclusions, future prospects and literature cited • communicate significant findings in the form of scientific papers, reports, poster and oral presentations			
19.	**BOT 509L** Plant Science Lab I	After successful completion of the course, students should be able to: • explain the puzzles of lower plants i.e., crytpogams • attain the knowledge about the life cycle, morphology, anatomy of important taxa of these plant groups • learn microscopy, anatomy, staining techniques which	Morphological and anatomical study of representative members of the following groups using whole mount preparations, dissections and sections: 1. **Algae:** Cyanophyta (*Microcystis*, *Stigonema*), Prochlorophyta (*Prochloron*), Chlorophyta (*Chlorella Hydrodictyon*, *Nitella*), Xanthophyta (*Botrydium*), Bacillariophyta (*Navicula*), Phaeophyta (*Dictyota*). 2. **Lichens** Crustose, Foliose, Fruticose forms of lichens. 3. **Fungi**	**BOT 530L: Plant Science Lab I** **Algae:** 1. Microscopy:- Light and simple microscope, Bright field microscopy, Flurescence microscopy ,SEM, TEM and applications of these microscopy in phycological study. **2.** Study of the vegetative and reproductive structures of members of the following groups - Cyanophyta (*Lyngbya*, *Scytonema*, *Hapalosiphon*).	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
		are basis of botany • recognize exact ways of training regarding lower plants and can address issues related to importance of these plants in our ecosystem. • Associate symptoms to pathogens of a particular disease • Understand applications of tissue culture	Myxomycota (*Plasmodiophora*), Mastigomycotina (*Peronospora*), Zygomycotina (*Mucor*), Ascomycotina (*Aspergillus, Erysiphe*), Basidiomycotina (*Puccinia, Ustilago*), Deutromycotina (*Fusarium*). 4. **Bryophyta** Metzgeriales (Metzgeria), Jungermanniales (Porella), Marchantiales (Plagiochasma, Lunularia, Cyathodium), Sphagnales (Sphagnum), Polytrichales (Polytrichum), Bryales (Physcomitrium). 5. **Pteridophytes**: Morphology and anatomy of vegetative and reproductive part of *Psilotum, Lycopodium, Selaginella, Equisetum, Gleichenia, Isoetes, Ophioglossum, Botrychium, Pteris.* 6. **Gymnosperms:** Morphology and anatomy of vegetative and reproductive part of *Cycas*, *Ginkgo*, *Cedrus*, *Abies*, *Picea*, *Cupressus*, *Araucaria*, *Cryptomeria*, *Taxodium*, *Pedocarpus*, *Agathis*, *Taxus*, *Ephedra* and *Gnetum* and the members in their natural habitat found in your locality. Study of important fossils of Pteridophytes and Gymnosperms from specimens. 7. Preparation of media for tissue culture. 8. Embryo culture. **Suggested Books:** ➢ Bendre, A. & Kumar, A. (2018). *A Text book of Practical Botany* Vol -I. Rastogi Publications, Meerut (India). ➢ Chaudhary, S.S., Chaudhary, P. & Prasad, T. (2010). *Practical Botany* (Cryptogams and	- Chlorophyta (*Chlamydomonas, Oedogonium, Zygnema, Cladophora, Trentepohlia, Chara, Nitella*). - Rhodophyta (*Polysiphonia, Compsopogon*). - Euglenophyta (*Euglena*). Heterokontophyta- Xanthophyceae (*Vaucheria*). - Phaeophyceae (*Padina/ Sargassum*). **Fungi:** 3. Methods of sterilization: Autoclave, hot air oven, incubator, laminar air flow; principles and methods of sterilization. 4. Preparation of fungal culture media; Basic idea about different types of fungal culture media, media preparation and preparation of slants, stabs and Petri-plates. 5. Demonstration on sub culturing-- fungal sub culture techniques. 6. Study of the vegetative and reproductive structures of members of the following groups - Myxomycota (*Plasmodiophora*), - Mastigomycotina (*Peronospora*), - Zygomycotina (*Rhizopus, Mucor*), - Ascomycotina (*Saccharomyces Ascobolus, Xylaria, Erysiphe*), - Basidiomycotina (*Agaricus, Polyporus, Pleuratus*), - Deutromycotina (*Fusarium, Alterneria*). **Plant Pathology:**	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
			Gymnosperms). CBS Publishers and Distributors. India. ➢ Kumar, S., Mishra, S. & Mishra, A.P. (2008). *Plant Tissue Culture: Theory and Techniques*. Scientific Publishers. India. ➢ Pandey, B.P. (2011). *Modern Practical Botany*, Vol-I. S. Chand Publishing, India ➢ Pandey, B.P. (2018). *Botany for Degree Students*. S. Chand Publishing, India	7. Method of subculturing, isolation of fungal and bacterial pathogens from plant tissue, establishment of pure culture, their maintenance and preservation. Inoculation technique. 8. Study of symptomology and histopathology and identification of some common plant diseases caused by fungi, bacteria and viruses.. 9. Identification of few fungal pathogens in the course by microscopic examination. 10. Spectrophotometric estimation of total phenols in diseased and healthy plant tissue. 11. Assay of cellulolytic enzymes produced by pathogens during pathogenesis. **Bryophyta and Pteridophyta** 12. Morphological and anatomical study of representative members of the following groups using whole mount preparations, dissections and sections: - **Bryophyta** Metzgeriales (Metzgeria), Jungermanniales (Porella), Marchantiales (Plagiochasma, Lunularia, Cyathodium), Sphagnales (Sphagnum), Polytrichales (Polytrichum), Bryales (Physcomitrium). - **Pteridophytes**: Morphology and anatomy of vegetative and reproductive part of *Psilotum*, *Lycopodium*, *Selaginella*, *Equisetum*, *Gleichenia*, *Isoetes*, *Ophioglossum*, *Pteris.*	

S. No	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
				Cell and Tissue Culture Technology: 13. Preparation of media for tissue culture. 14. Establishment of callus cultures. 15. Cell suspension cultures. 16. To perform embryo culture from germinated mung bean seeds. 17. Shoot tip culture. 18. Protoplast culture and somatic hybridization.	

* Matter in contrast (black background & white letters) is shifted to some other units, and material brought as a result of shift is also in contrast.
# Matter in square brackets, bold, italic and crossed is deleted.
@ Proposed added materials are shaded in grey.

M.Sc. Bioscience (Plant Science) IV Semester					
	BOT 501 Angiosperms	After successful completion of the course, students should be able to: • Increase their capacity to think critically; ability to design and execute an experiment; confidence and ability in communicating ideas. • This will serve as a lasting and practical basis for a career, for example, in research whether industry or academia - as well as teaching, media, law, commerce, government or management.	**BOT 501** Angiosperms **Section-A** • Botanical explorations, historical perspectives. Botanical survey of India, its organization and role. Botanical nomenclature, History ICBN, Familiarity with botanical literature, monographs, icones, floras, important periodicals with emphasis on Indian floristics, methods of literature consultation. • Phytogeography with reference to discontinuous areas, endemism, floristic regions of the world. Principles of plant classification with emphasis on modern tools of taxonomy: cyto-, chemo-, palyno- and Numerical taxonomy: Taxonomy as a synthetic discipline; utility of taxonomy; biosystematics. Phylogenetic systems of classification with emphasis on comparative critical study of: Engler & Prantl, APG system of	**BOT 528: Morphology, Anatomy and Taxonomy of Angiosperms** **Section-A** • Botanical explorations, historical perspectives. Botanical survey of India, its organization and role. Botanical nomenclature, History ICBN, ICN, Familiarity with botanical literature, monographs, icones, floras, important periodicals with emphasis on Indian floristics, methods of literature consultation. • Phytogeography with reference to discontinuous areas, endemism, floristic regions of the world. • Principles of plant classification with emphasis on modern tools of taxonomy: morpho-, cyto-, chemo-, palyno- and Numerical taxonomy: Taxonomy as a synthetic discipline; utility of taxonomy; biosystematics. Natural System of Classification, Bentham and Hooker,	New course proposed by modification of the existing course and incorporation of Morphology and Anatomy portion which is essential for the understanding of Plant Sciences

			classification. • Phylogeny of Angiosperms: Origin, evolution, and interrelationships in dicots and monocots Interesting taxonomic features and phylogeny of the following families: – ***Dicotyledons*:** Magnoliaceae, Nymphaeaceae, Ranunculaceae, Papaveraceae, Fumariaceae, Caryophylaceae, Bombacaceae, Malvaceae, Cucurbitaceae, Capparaceae, Brassicaceae, Rosaceae, Fabaceae, Myrtaceae, Rutaceae, Apiaceae, Apocynaceae, Asclepiadaceae, Solanaceae, Convolvulaceae, Cuscutaceae, Boraginaceae, Orobanchaceae, Acanthaceae, Rubiaceae, Asteraceae, Lamiaceae, Verbenaceae, Bignoniaceae, Moraceae, Cannabinaceae, Fagaceae, Betulaceae, Juglandaceae, Casuarinaceae, Nyctaginaceae, Chenopodiaceae, Amaranthaceae, Polygonaceae. – ***Monocotyledons:*** Alismatacea, Commelinaceae, Cyperaceae, Poaceae, Cannaceae, Arecaceae, Araceae, Lillaceae, Amaryliidaceae, Agavaceae, Smilacaceae and Orchidaceae. **Section B** • Origin, growth, differentiation and ultra structure of cells and tissues. Meristems: structure and kinds; theories concerning root and shoot apices; organogenesis. Structure, ultra structure ontogeny and evolution of primary secondary xylem and phloem indicating their phylogenetic role. • Normal and anomalous functioning of vascular cambium: cork cambium-periderm formation,	Phylogenetic systems of classification: Engler & Prantl, Takhtajan; Outline of APG system (APG I - APGG IV) of classification. **Section B** Morphology: • Habit and habitat, root, stem, leaves, inflorescence, flower, fruit, floral diagram and formula. Anatomy • Origin, growth, differentiation and ultra-structure of cells and tissues. Meristems: structure and kinds; theories concerning root	

			abscission and wound healing. • Structural variability in leaves, leaf histogenesis, leaf meristem, origin, development and ultra structure of trichomes and stomata. • Comparative anatomy of typical dicot and monocot roots, stems and leaves. • Anomalies in the primary and secondary root and stem structures. • Organogamy of floral parts and floral biology. **Section C** • ~~Historical perspective of the development of our knowledge in Embryology.~~ • ~~Microsporangium structure and function of wall layers, nuclear behaviour in tapetum, microsporogenesis, microgametogenesis.~~	and shoot apices; organogenesis. Structure, ultra structure ontogeny and evolution of primary secondary xylem and phloem indicating their phylogenetic role. • Normal and anomalous functioning of vascular cambium: cork cambium-periderm formation, abscission and wound healing. • Adaptive and Protective Systems: Epidermal tissue system, cuticle, epicuticular waxes, trichomes(uni-and multicellular, glandular and nonglandular,), stomata (classification). • Structural variability in leaves, leaf histogenesis, leaf meristem, origin, development and ultra-structure of trichomes and stomata. • Comparative anatomy of typical dicot and monocot roots, stems and leaves. • Secondary growth in root and stem, Types of rays and axial parenchyma; Sapwood and heartwood; Ring and diffuse porous wood; Early and late wood, tyloses; Dendrochronology. • Anomalies in the primary and secondary root and stem structures. • Floral anatomy: Organogamy of floral parts and floral biology. **Section C** • Select Families of Angiosperms: Origin, evolution, and interrelationships in dicots and monocots • Phylogeny of plants: the archetypes of plants; evolution in major groups of plants. Phylogeny	

			• ~~Megasporangium structure, development and kinds of ovules, Morphological nature of ovules, megasporogenesis and megagametogenesis, embryo sac types and morphological nature of the embryo sac.~~ • ~~Pollination natural and artificial, self and interspecific incompatibility, methods of overcoming incompatibilities. Fertilization syngamy and triple fusion, post fertilization changes in ovules and embryo sac.~~ • ~~Endosperm: structure, kinds and morphological nature, endosperm haustoria, pseudo embryo sac, xenia, metaxenia. mosaic endosperm, endosperm culture.~~ • ~~Embryo: structure and kinds of embryo development, embryo culture.~~ • ~~Apomixis: vegetative propagation and agamospermy (adventive embryony, apospory and diplospory), parthenogenesis.~~ • ~~Polyembryony: origin, kinds and significance.~~ **Suggested Books:** ➢ Alam, A., & Sharma, V. (2013). *Text Book of Economic Botany*. India: Pointer Publishers. ➢ Bhojwani, S.S., Bhatnagar , S.P. & Dantu, P.K. (1979). *The Embryology of Angiosperms* (6th ed.). India: Vikas Publishing House. ➢ Gary, L. (2011). *Flowering Plants: A Pictorial Guide to the World Flora*. Firefly Books, Canada: Richmond Hill. ➢ Hill, A.F. (1952). *Economic Botany A Textbook of Useful Plants and Plant Products*. McGraw-Hill.	of flowering plants: Basal flowering plants and Eumagnoliids • Interesting taxonomic features and phylogeny of the following families: • Dicotyledons: Magnoliaceae, Nymphaeaceae, Ranunculaceae, Papaveraceae, Fumariaceae, Caryophylaceae, ~~Bombacaceae~~, Malvaceae, Cucurbitaceae, Capparaceae, Brassicaceae, Rosaceae, Fabaceae, Myrtaceae, Rutaceae, Apiaceae, Apocynaceae, ~~Asclepiadaceae,~~Solanaceae, Convolvulaceae, ~~Cuscutaceae,~~Boraginaceae,~~Orobanchaceae,~~ Acanthaceae, Rubiaceae, Asteraceae, Lamiaceae, Verbenaceae, Bignoniaceae, Moraceae, ~~Cannabinaceae,~~Fagaceae, ~~Betulaceae, Juglandaceae~~, Casuarinaceae, Nyctaginaceae, Chenopodiaceae, Amaranthaceae, Polygonaceae. • Monocotyledons: Alismatacea, Commelinaceae, Cyperaceae, Poaceae, Cannaceae, Arecaceae, Araceae, Lillaceae, Amaryliidaceae, Agavaceae, Smilacaceae and Orchidaceae. Suggested Books: **Suggested Books:** ➢ Alam, A., & Sharma, V. (2013). Text Book of Economic Botany. India: Pointer Publishers. ➢ ~~Bhojwani, S.S., Bhatnagar , S.P. &Dantu, P.K. (1979). The Embryology of Angiosperms (6th ed.). India: Vikas Publishing House~~. ➢ Gary, L. (2011). Flowering Plants: A Pictorial Guide to the World Flora. Firefly Books,	

			➢ Judd, W.S., & Campbell, C.S. (2007). *Plant Systematics A Phylogenetic Approach*. New York: Sinarue Publication. ➢ Lawrence, G.H.M. (2017). *Taxonomy of Vascular Plants.* Jodhpur (Raj.): SENTIFIC Publishers. ➢ Zomlefer, W.B. (1995). *Flowering Plant Families*. USA: University of North Carolina Press. **Suggested e-Resources:** ➢ **Angiosperms: General account and Classification** https://www.toppr.com/guides/biology/plant-kingdom/angiosperms/ ➢ **Angiosperms: Taxonomy and evolution** https://www.britannica.com/plant/angiosperm ➢ **Angiosperms: Tree of Life Web project** http://tolweb.org/Angiosperms ➢ **Angiosperms: General account** http://landau.faculty.unlv.edu//angiosperms.htm ➢ **Angiosperm: Recent nomenclatural** www.theplantlist.org ➢ **Angiosperm: Palynology** https://www.floridamuseum.ufl.edu/index.php/paleobotany/palynology/about/ https://www.environmentalscience.org/palynology	Canada: Richmond Hill. ➢ Hill, A.F. (1952). Economic Botany A Textbook of Useful Plants and Plant Products. McGraw-Hill. ➢ Judd, W.S., & Campbell, C.S. (2007). Plant Systematics A Phylogenetic Approach. New York: Sinarue Publication. ➢ Lawrence, G.H.M. (2017). Taxonomy of Vascular Plants. Jodhpur (Raj.): Scientific Publishers. ➢ Zomlefer, W.B. (1995). Flowering Plant Families. USA: University of North Carolina Press. Suggested e-Resources: **Angiosperms**: General account and Classification https://www.toppr.com/guides/biology/plant-kingdom/angiosperms/ Angiosperms: Taxonomy and evolution https://www.britannica.com/plant/angiosperm Angiosperms: Tree of Life Web project http://tolweb.org/Angiosperms Angiosperms: General account http://landau.faculty.unlv.edu//angiosperms.htm Angiosperm: Recent nomenclatural www.theplantlist.org ~~Angiosperm: Palynology~~ ~~https://www.floridamuseum.ufl.edu/index.php/paleobotany/palynology/about/~~ ~~https://www.environmentalscience.org/palynology~~	
20.	**BOT 504** Cytogentics	After successful completion of the course, students should	**Section A** • Architecture of chromosome in prokaryotes and	No change in the existing syllabus	

	and Plant Breeding	be able to: • understand the chromosomal theory of inheritance and cytological & evolutionary consequences of polyploidy and aneuploidy on fertility in plants • learn about the fundamental concepts in cytogenetics • gain knowledge of the basic diagnostic tools of cytogenetics • familiarize with the common chromosomal aberrations and their evolutionary consequences in plants and animals • understand the implications of chromosomal structural variation to plant breeding • attain the ability to operate basic consideration in order to analyze genetic data from cytogenetic diagnostic. An ability to incorporate cytogenetic considerations in breeding programs, in evolutionary studies, and in genetic analyses	eukaryotes; Chromonemata, chromosome matrix, chromomeres, centromere, secondary constriction and telomere; artificial chromosome construction and its uses; special types of chromosomes. • Introduction to techniques for karyotyping; Chromosome banding and painting - *in situ* hybridization and various applications • Origin, cytology, effect & uses of structural chromosomal aberrations. • Numerical variations of chromosomes and their implications. **Section B** • History of Plant Breeding (Pre and post-Mendelian era); objectives of plant breeding, characteristics improved by plant breeding; patterns of evolution in Crop Plants; Centres of Origin; biodiversity and its significance. • Genetic basis of breeding self- and cross - pollinated crops, including mating systems and response to selection - nature of variability, components of variation; Heritability and genetic advance, genotype environment interaction. • General and specific combining ability. • Self-incompatibility and male sterility in crop plants and their commercial exploitation. **Section C** • Plant introduction and role of plant genetic resources in plant breeding. • Pure line theory, pure line selection and mass selection methods; Line breeding, pedigree, bulk, backcross, single seed descent and multiline		

			method; Population breeding in self-pollinated crops • Breeding methods in cross pollinated crops; Population breeding-mass selection and ear-to-row methods; S1 and S2 progeny testing, progeny selection schemes, recurrent selection schemes for intra and interpopulation improvement and development of synthetics and composites; Hybrid breeding - heterosis and inbreeding. • Improvement of Rice, Wheat & Maize through breeding in India. **Suggested Books:** ➢ Allard, R. W. (1999). *Principles of Plant Breeding* (II ed.). Willey. ➢ Brown, J., Caligari, P.D.S. & Campos, H.A. (2014). Plant Breeding (II ed.). Wiley Blackwell. ➢ Gupta, P.K. (2005). *Cytology Genetics and Evolution*. Meerut: Rastogi Publications ➢ Gupta, P.K. (2007). *Cyotgenetics*. Meerut: Rastogi Publications. ➢ Hayes, H. & Immer, F.R. (2015). *Methods of Plant Breeding*. Create Space Independent Publishing Platform¸ Scotts Valley, California, United States. ➢ Mahabal, R. (2014). *Plant Breeding Methods*. Delhi: PHI Learning Private Ltd. ➢ Singh, B.D. (2009). *Plant Breeding, Principles & Methods*. Kalyani Publications. **Suggested E resources:** ➢ **Resource documents of the Genetic Engineering Appraisal Committee, Govt. of India**. http://www.geacindia.gov.in/resource-		

			documents.aspx ➢ **Biology of Rice, Series of Crop specific Biology Documents, Ministry of Environment and Forests, DBT, Govt. of India** http://www.geacindia.gov.in/resource-documents/biosafety-regulations/resource-documents/Biology_of_Rice.pdf ➢ **Biology of Maize, Series of Crop specific Biology Documents, Ministry of Environment and Forests, DBT, Govt. of India** http://www.moef.gov.in/divisions/csurv/geac/Biology_of_Maize[1].pdf ➢ **Impact of Public and Private Sector Maize Breeding Research, CYMMYT.** https://repository.cimmyt.org/bitstream/handle/10883/1034/75341.pdf?sequence=1&isAllowed=y		
21.	**BOT 507** Plant Pathology	**After successful completion of the course, students will be able to:** • Facilitate to develop learning goals and objectives in their courses and programs, in prioritizing and focusing the learning experiences, and in the selection of appropriate assessment tools. • Potential students and outside agencies to assess the quality of our	**Section A** • Host parasite relationship, Infection, development and establishment of the disease. • Epiphytotics: Compound and simple interest diseases, mathematical model, essential condition and analysis. • Effect of environment in epidemiology of the disease. • Genetic variability of plant pathogens. • Genetic basis of host pathogen interactions, its role in specificity of plant disease. **Section-B** • Plant disease control: Physical, Chemical and Biological (Biocontrol, Breeding, Genetic Engineering).		The course Plant Pathology is shifted to third semester with suitable modifications..

		academic programs. • These learning outcomes areas include: Scholar, content and technical • expertise, social accountability, communicator, and professional.	• A general account of diseases caused by Bacteria, Viruses and *Mycoplasma*. • Bacterial diseases: Red stripe of sugarcane, Angular leaf spot of cotton, Soft rot of vegetables. • Viral diseases: Leaf roll of potato & tomato, Mosaic disease of tomato. • Mycoplasma diseases: Sandal spike, Sesamum phyllody, Little leaf of Brinjal. **Section-C** • Fungal diseases of cereals and millets: Rusts of wheat, Loose and covered smut of wheat and Barley, fungal diseases of Bajra, Charcoal rot of Maize. • Fungal diseases of vegetables and fruits: Early blight of Potato, Wart disease of Potato, Powdery mildew of Cucurbits & Pea, Die back of Chillies, Tikka disease of Groundnut, Wilt & root rot of Gram, Red rot and smut of Sugarcane. • Nematode diseases: Root knot of vegetable (Cucumber), Molya disease of Wheat and Barley. • Insect diseases: General account of plant and animal galls with special reference to Mango & Ziziphus. **Suggested Books:** ➢ Agrios, G.N. (2005). *Plant Pathology*. USA: Elsevier Publication. ➢ Alexopoulus, C.M. (1996). *Introductory Mycology*. New York: John Wiley and Sons. ➢ Bilgrami, K.S. & Dubey, H.C. (1998). *Text Book of Modern Pathology*. India: Vikas Publishing House Pvt. Ltd.		

			➢ Biswas, S. B. & Biswas, A. (2006) *An Introduction to Viruses*. India: Vikas Publishing House Pvt. Ltd. ➢ Butler, E.J. (1918). *Fungi and Diseases in Plants*. Kolkata: Thanker Spink and Co. ➢ Mehrotra, R.S. (1990). *Plant Pathology*. Tata McGraw Hill Publication Co. ➢ Mundkur, B. (1967). *Fungi and Plant Diseases*. Macmillan and Co. Limited ➢ Singh, R.S. (2017). *Plant Disease*. IBH, New Delhi: Oxford. **Suggested e-Resources:** ➢ **Fungi: *Aspergillus*** https://www.aspergillus.org.uk/content/mycology-online ➢ **Plant Pathology** https://www.apsnet.org/publications/apsnetfeatures/Pages/ICPP98PlantPath.aspx ➢ **Plant diseases: Identification and Control** https://www.planetnatural.com/pest-problem-solver/plant-disease/ ➢ **Plant disease control** http://cemerced.ucanr.edu/files/40658.pdf		
22.		After successful completion of the course, students should be able to: • understand the phylogeny of Gymnosperms. • know the evolution of sporophytes • understand the vascular evolution and seed		**BOT 527:** Gymnosperms, Paleobotany and Palynology **Section A** ➢ General diagnostic features of gymnosperms with special reference to drop mechanism, vessel less and fruitless seed plants. ➢ General account of anatomical variations in gymnospermic leaves (*Cycas , Pinus , Abies, Cedrus, Picea,* and *Taxus, Gnetum*) ➢ Outline classification of gymnosperms as	Gymnosperms have been shifted from third semester to fourth semester, necessary modifications are made. Paleobotany and Palynology.

		formation habit • gain knowledge about life cycles of gymnosperm plants. • explain about fossils and fossilization.		proposed by Sporne (1965) and Sandra Holms (1986), Classification (Stewart and Rothwell (1993) up to order) distribution of gymnosperms with special reference to India. ➢ Economic importance of gymnosperms. A study of morphology, Anatomy, and outline life history of the following: - Class 1: Pteidospermopsida: Cycadofilicales : Lyinopteridaceae-*Lyginopteris* Glossopteridales : Glossopteridaceae-*Glossopteris*, - Class 2: Cycadopsida Cycadales : Cycadaceae-*Cycas* Cycadeoidales : Cycadeoideaceae -*Cycadeoidea* (*Bennittites*), - Class 3: Ginkgopsida Ginkgoales: Ginkgoaceae – *Ginkgo* - Class 4: Other gymnosperms (Gymnosperms of uncertain affinities) Pentoxylales: Pentoxylaceae-*Pentoxylon* - Class 5: Coniferopsida Coniferales: Pinaceae – *Pinus* - Class 6 Gnetopsida: Welwitschiales: Welwitschiace *Welwitschia* Gnetales - Gnetaceae *Gnetum*	

				Section B ➢ Introduction to Paleobotany and its significance. ➢ Introductory idea of correlation and stratigraphy; stratigraphic deductions based on plant fossils. ➢ Age of the earth, Geologic Time Scale, major events of plant life through geologic time ➢ Process of fossilization, types of fossils on the basis of their preservation; Fossil formation, types of fossils. ➢ Study of fossil Bryophyte (*Naiadita*); fossil Pteridophytes (*Sphenophyllum Calamites*); fossil Gymnosperm (*Williamsonia, Pentoxylon*) **Paleobotany in India** ➢ Brief study of the fossil deposits in India ➢ Important Indian Paleobotanical Institutes, ➢ Contributions of Prof. Birbal Sahni in Indian Paleobotany **Section C** ➢ Introduction; Morphology and functional significance of spores and pollen ➢ ➢ Spore/pollen morphology with reference to polarity, size, shape, symmetry, aperture and sculpture. ➢ Palynomorphs of the Paleozoic and Mesozoic period ➢ Diagnostic features of pteridophyte spore	

				and angiosperm pollen, and the early fossil record. ➢ Types of Pollen: Magnoliid pollen, Monocot pollen, Lower Eudicot pollen types ➢ Selected pollen types of Rosid and Asterid ➢ Applications of Palynology: forensics, honey, paleoenvironmental study and taxonomy. **Suggested Books:** ➢ Chamberlain CJ, 1935. Gymnosperms: Structure and Evolution.Chicago University Press. ➢ CoutlerJ M, CJ Chamberlain, 1958.Morphology of Gymnosperms.Central book depot.Allahabd. ➢ Sporne K R, 1967.The Morphology of Gymnosperms.Hutchinson and Co. Ltd. London. ➢ Sreevastava H N, 1980. A Text Book of Gymnosperms. S Chand and Co. Ltd., New Delhi. ➢ Vasishta P C, 1980. Gymnosperms.S Chand and Co., Ltd., New Delhi. ➢ Maarten JM, Christenhusz, James L Reveal, AljosFarjon, Martin F Gardner, Robert R Mill, Mark W Chase, 2011.A new classification and linear sequence of extinct gymnosperms.Phytotaxa,19: 55 – 70.	

				➢ Campbell H D, 1940. The Evolution of land plants (Embryophyta).Univ. Press, Stanford. ➢ Bower F O, 1935. Primitive Land Plants.Cambridge, London. ➢ Chandra S, Srivastava M, 2003. Pteridology in New Millennium.Kluwer Academic Publishers. ➢ Eames AJ, 1979. Morphology of vascular plants, lower group.Wiley International edition, New Delhi. ➢ Parihar NS, 1977. Biology and Morphology of Pteridophytes. Central Book Depot, Allahabad. ➢ Rashid A, 1976. An Introduction to Pteridopyta.Vikas publ. Co., New Delhi. ➢ Ranker T A, Haufler C H (eds.), 2008.Biology and Evolution of Ferns and Lycophytes.Cambridege University Press. ➢ Mehltreter K, Walker LR, Sharpe J M (eds), 2010. Fern Ecology.Cambridge University Press. ➢ Smith AR, Pryer KM, Schuttpelz E, Korall P, Schnelder H, Wolf PG, 2006. A Classification for extinct Ferns. Taxon 53:705731. ➢ Smith AR, Pryer KM, Schuettpelz E, 2008. Fern classification. In: T. A. Rankerand C.H. Haufler (eds.). Biology and Evolution	

				of Ferns and Lycophytes.Cambridge University press, UK. ➢ Paleopalynology. 2nd Edition Alfred Traverse 2001 ➢ ~~W. Rothwell and Wilson Nichols Stewart. Paleobotany and the Evolution of Plants~~ ➢ Edith L. Taylor, Michael Krings, and Thomas N. Taylor. The Biology and Evolution of Fossil Plants (2nd Ed.) ➢ Tayloe EL, Taylor TN and Krings M.2009. Palaeobotany: The Biology and Evolution of Fossil Plants, 2nd Ed., Academic Press. ➢ Stewart WN and Rothwell GW. 2010. Paleobotany and the Evolution of Plants. 2nd Ed, Cambridge University Press	
23.	**BOT 508 Plant Physiology**	After successful completion of the course, students should be able to: •demonstrate understanding of the organization of plants from the level of cells through tissues, tissue systems, and organs • demonstrate understanding of developmental patterns and processes of plants • demonstrate understanding of organellar function at the	**Section-A** • Assimilation of Carbon in Plants. • Photosynthetic pigments, their distribution & functions. • Mechanism of Photosynthesis, Photosynthetic electron transport chain (Photophosphoryation). • Carbon dioxide reduction cycles in C3 & C4 Plants: Enzymes of C3 & C4 cycles & their location in the chloroplast. • Photorespiration: pathway, enzymes & metabolic significance. • Crassulacean acid metabolism (CAM) in plants. **Section-B**	No change in the existing syllabus	

		cellular level of architecture • demonstrate understanding water potential and its effect on cellular function • demonstrate detailed understanding of the physiological mechanisms involved in the uptake and transport of water and the translocation of food by plants • demonstrate understanding of the cellular establishment of membrane potential and its role in solute transport • demonstrate understanding of the mechanisms for procurement of mineral ions by plants and mineral nutrition and the role these minerals play in organic molecule synthesis and use	• Cell wall: Structure & functions, microfibril & matrix polysaccharides, proteins, lignins. • Plant growth regulators: Physiological importance & mechanism of action of (a) Auxins (b) Gibberellins (c) Cytokinins (d) Abscissic acid (e) Ethylene. ▪ Nitrogen Metabolism: Nitrate and nitrite reduction; Nitrogen fixation; mechanism and enzymes. • Role of temperature and light in plant development with reference to Photoperiodism & vernalization. • Phytochrome: Structure, function and mechanism of action. **Section-C** • Dormancy: Nature and forms of dormancy, Mechanism of dormancy, Methods of breaking dormancy, Physiological basis of dormancy. • Macro & Micronutrients: Availability & Uptake, Role & specific functions of plant nutrients. • Biosynthesis of secondary metabolites, Major pathways: Shikimic acid, Acetate-malonate & acetate - mevalonate pathways. • Physiological importance of secondary metabolites. S**uggested Books:** ➢ Buchanan, B.B., Greissum, G., & Jones, R.L. (2015*). Biochemistry and Molecular Biology of Plants*. Wiley Blackwell. ➢ Devlin, R.M. & Witham, F.H. (1969). *Plant Physiology*. New York: Van Norstand. ➢ Hopkins, W.G., & Huner, N.P.A. (2009). *Introduction to Plant Physiology*. John Wiley and		

			Sons Inc. ➢ Noggle, G.R. & Fritz, J.F. (1976). *Introductory Plant Physiology*. New Delhi: Prentice Hall of Pvt. ➢ Pandey, S.N., & Sinha, B.K. (2005). *Plant Physiology*. New Delhi: Vikas Publishing House Pvt. Ltd. ➢ Salisburry, F.B. & Ross, CW (1974). *Plant Physiology*. New Delhi: Prentice Hall of India. ➢ Taiz, L. & Zeiger, E. (2010). *Plant Physiology*. London: Sinauer Associate. **Suggested e-Resources** ➢ **Plant Physiology: Online course** https://has.nl/en/training/online-course-plant-physiology ➢ **Plant Physiology: Recent researches** http://www.plantphysiol.org/ ➢ **Plant Physiology: Online content** http://www.plantphysiol.org/content/by/year		
24.	**BOT 510L** Plant Science Lab-II	After successful completion of the course, students will be able to: • Explain and justify the use of advanced techniques in taxonomy, microscopy, cytology, cyto-genetics, genotyping and plant physiology, and to interpret the results of such analyses. • Identify the pollen grains of gymnosperms and angiosperms.	**BOT 510L** Plant Science Lab-II 1. Morphotaxonomical and anatomical study of available plants mentioned in the syllabus. 2. Emasculation technique. 3. Preparation of various chemicals used for fixation, dehydration, staining and cleaning etc. for light microscopy. 4. Chromosome banding technique. 5. Study of Mitosis and Meiosis. 6. Study of endomitosis using endosperm of *Cocos nucifera.* 7. Preparation of MS media and demonstration of efficacy of growth hormones for the induction of shoot & root.	**BOT 531L: Plant Science Lab-II** 1. Morphotaxonomical and anatomical study of available plants mentioned in the syllabus. 2. Emasculation technique. 3. Preparation of various chemicals used for fixation, dehydration, staining and cleaning etc. for light microscopy. 4. Chromosome banding technique. 5. Study of Mitosis and Meiosis. 6. Study of endomitosis using endosperm of *Cocos nucifera.* 7. Preparation of MS media and demonstration of efficacy of growth hormones for the induction of shoot & root.	Modifications done as per changes syllabus in some of the courses

		• Explain the process of fossilization and its evolutionary significance. • Utilize technical skills acquired through lab experience and apply these skills in formulating solutions to life science questions. • Communicate proficiently through oral and written scientific media. • Identify specific ways training in plant science that can address issues of earthly stewardship and sustainability, and demonstrate a strong desire to help Mankind in a socio-scientific way.	8. Estimation of Chlorophyll pigments. 9. Separation of plant pigments by TLC/Paper chromatography. 10. Isolation of chloroplast and demonstration of Hill's activity. 11. Calculation of RQ of Carbohydrates, fatty acids, and organic acids by Ganong's respirometer. 12. Extraction and analysis of phytochemicals from plant samples. 13. Screening of seed borne fungi by Blotter technique/Agar plate method. 14. Study of important bacterial, fungal and viral diseases of plants mentioned in the syllabus. 15. Preparation of slides and identification of plant pathogens. 16. Effect of temperature/pH/RH on the growth of fungi.	8. Estimation of Chlorophyll pigments. 9. Separation of plant pigments by TLC/Paper chromatography. 10. Isolation of chloroplast and demonstration of Hill's activity. 11. Calculation of RQ of Carbohydrates, fatty acids, and organic acids by Ganong's respirometer. 12. Extraction and analysis of phytochemicals from plant samples. 13. Screening of seed borne fungi by Blotter technique/Agar plate method. 14. Study of important bacterial, fungal and viral diseases of plants mentioned in the syllabus. 15. Preparation of slides and identification of plant pathogens. 16. Effect of temperature/pH/RH on the growth of fungi. **Gymnosperms:** 17. Morphology and anatomy of vegetative and reproductive part of *Cycas*, *Araucaria*, *Pinus*, *Ephedra*, *Gnetum* 18. Study of important fossils of Pteridophytes and Gymnosperms from specimens. **Palynology**: 19. Microscopic study of available spores of Pteridophytes and pollens of gymnosperms, monocots and dicots. **Paleobotany:** 20. Study of available specimens of plant fossils. **Suggested Books:** ➢ Bendre, A. & Kumar, A. (2018). *A Text book of Practical Botany* Vol -I. Rastogi Publications,	

				Meerut (India). ➢ Chaudhary, S.S., Chaudhary, P. & Prasad, T. (2010). *Practical Botany* (Cryptogams and Gymnosperms). CBS Publishers and Distributors. India. ➢ Kumar, S., Mishra, S. & Mishra, A.P. (2008). *Plant Tissue Culture: Theory and Techniques*. Scientific Publishers. India. ➢ Pandey, B.P. (2011). *Modern Practical Botany*, Vol-I. S. Chand Publishing, India ➢ Pandey, B.P. (2018). *Botany for Degree Students*. S. Chand Publishing, India	
Proposed Elective courses to be offered in III & IV Semester					
1)	**BOT Phycology-I**	After successful completion of the course, students should be able to: • identify these algal forms in their surroundings and will be motivated to better understand this interesting branch of botany • know the basis of photosynthesis with amazing diversification in these plants • be placed as researchers in marine research, space research and biofuel research institutes	**BOT Phycology-I** **Section A** • Diagnostic characters of major algal division Cyanophyta, Glaucophyta, Chlorophyta, Dinophyta, Phaeophyta and Rhodophyta. • Principles, criteria (pigments, cell wall, flagellation, food reserve and eye spots) and systems of classification. • Modern criteria of algal classification with special emphasis on chloroplast ultra structure, flagella and pigments. • Biodiversity and Conservation of Algae: Habit and Habitat diversity, Importance of Conservation: *in situ* and *ex situ* conservation. • Wetlands and Algal assemblages: Role of Algae in Wetlands and structural Environment. • Work done on freshwater algae with special reference to India & Contributions of Prof. M. O.	**BOT Phycology-I** **Section A** • Modern criteria of algal classification with special emphasis on chloroplast ultrastructure, flagella and pigments. • A brief study of the following classes of algae and special significance of these groups.: - Pryrnnesiophyceae - Raphidophyceae - Chrysophyceae - Dinophyceae - Chlorarachniophyceae - Synurophyceae - Prasinophycee • Comparative account of algal pigments; light microscopic structure, ultrastructure, function and importance of cell wall, flagella, chloroplasts, pyrenoids, eyespots, nucleus,	The course has been updated

			P. Iyengar. • Distribution pattern of Marine algae in Indian coasts. • Endosymbiosis theories and origin of Eukaryotic algae. **Section** B • Cyanophyta: cell structure, heterocyst and akinete development and Physiological aspect; chromatic adaptation, thallus organization and reproduction. • Alternation of generation in Phaeophyta and post-fertilization development and site of meiosis in Rhodophyta. **Section C** • A brief account of Xanthophyta, Chrysophyta, Bacillariophyta, Pyrrophyta, Euglenophyta, Eustigmatophyta, Prasinophyta and Prochlorophyta. • Algae in Specialized habitats, Phytoplankton diversity, algal blooms and Phycoviruses. • Algae as source of phycocolloids , types and Importance. • Algal Culture: brief idea and types. • Algae in Human welfare–Nutraceuticals, Pharmaceuticals, Biofertilizers, Biofuel , CO_2 Sequestration and pollution control. • Algal Biotechnology: Genome shuffling and evolutionary engineering ; application of Synthetic biology in algae. **Suggested Books:** ➢ Bilgrami, K.S. & Saha, L. (2007). *A textbook of Algae*. CBS Publishers and Distributors.	contractile vacuole and their importance in taxonomy. • Macroalgal and periphyton ecology: biogeography of seaweeds; influence of biological factors on periphyton. • Algae in Specialized habitats, Phytoplankton diversity, algal blooms and Phycoviruses. • Origin of Eukaryotic algae in light of endosymbiosis theory. • Fossil algae & their importance. • Wetlands and Algal assemblages: Role of Algae in Wetlands and structural Environment. • Work done on freshwater algae with special reference to India & Contributions of Prof. M. O. P. Iyengar. • Distribution pattern of Marine algae in Indian coasts. **Section** B • Cyanophyta: cell structure, heterocyst structure and akinete development and Physiological aspect; chromatic adaptation, thallus organization and reproduction. genetic recombination; affinities • Glaucophyta: Major impact on algal evolutionary aspect especially on endosymbiotic evidences. • Prochlorophyta: Diagnostic characters, Evolutionary Status and affinities • Chlorophyta: Evolutionary trends within group. Probable ancestor of land plant with evidences	

			➢ Kumar, H.D. & Singh, H.N. (1979). A textbook on Algae. Macmillan Publishers Limited. ➢ Nash, T.H. (2011). *Lichen Biology*. Cambridge University Press. Cambridge. ➢ Round, F.E. (1986). *The Biology of Algae*. Cambridge University Press, Cambridge. **Suggested e-Resources:** ➢ **Algae** https://www.livescience.com/54979-what-are-algae.html	• Heterokontophyta, Xanthophyceae, parallelism with green algae & affinities. • Phylogeny of algal plastids. **Section C** • Algae as source of phycocolloids, types with examples and Importance. • Algal Culture: brief idea and types. algal medium - BGA 11, Pringsheim medium • Algae in Human welfare: aquaculture, bioremediation, biodiesel, biocosmetics, bioethanol and hydrogen production, carbon sequestration, as health food; Industrial use of algae, photobioreactors and raceway ponds. • Extracellular products of algae & toxic algae. • Biogeochemical role of algae. • Isolation, purification & growth characteristics in relation to algal culture; indoor and outdoor cultivation • Algal Biotechnology: Genome shuffling and evolutionary engineering; application of synthetic biology in algae. **Suggested Books:** ➢ Lee, R. E. (2008). *Phycology*. Cambridge University Press, New York ➢ C.Vanden Hoek, D.G. Mann and H.M. Jahns (1995). Algae- An introduction to phycology, Cambridge University Press, New York ➢ Graham L E, Graham JM, and Wilcox L W (2009). Algae, Pearson	

				➢ Bilgrami, K.S. & Saha, L. (2007). *A textbook of Algae*. CBS Publishers and Distributors. ➢ Kumar, H.D. & Singh, H.N. (1979). A textbook on Algae. Macmillan Publishers Limited. ➢ Round, F.E. (1986). *The Biology of Algae*. Cambridge University Press, Cambridge. **Suggested e-Resources:** ➢ **Algae** https://www.livescience.com/54979-what-are-algae.html	
2)	**BOT** Phycology- II			No change in the existing syllabus	
3)	**BOT 515** Bryology-I	After successful completion of the course, students should be able to: • identify these Lilliputians of plant kingdom in their surroundings and will be able to collect those from their natural habitats hence motivated to better understand this fascinating group of plants • they will know the basis of thallus organization with amazing diversification • after passing this course they will be placed as researchers in various institutes and universities	**Section A** • General characteristics of bryophytes, alternation of generations and classification. • Evolution in bryophytes. • Life-cycle of bryophytes, asexual and sexual reproduction. **Section B** • Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders of the class Bryopsida: – Takakiales - Takakia – Sphagnales - *Sphagnum* – Andreaeales - *Andreaea* – Buxbaumiales - *Buxbaumia* – Bryales - *Physcomitrium, Fontinalis, Splachnum* – Polytrichales – *Polytrichum* **Section C** • Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders	No change in the existing syllabus	

			of the class Hepaticopsida. – Calobryales - *Calobryum*, *Haplomitrium* – Metzgeriales - *Pallavicinia*, *Riccardia*, *Metzgeria* – Jungermanniales - *Jungermannia*, *Porella*, *Ptychanthus*, *Radula* – Sphaerocarpales - *Riella*, *Sphaerocarpous* – Monocleales - *Monoclea* – Marchantiales - *Reboulia*, *Plagiochasma*, *Asterella*, *Lunularia*, *Dumortiera*, *Targionia*, *Cyathodium* **Suggested Books:** ➢ Alam, A. (2015). *Textbook of Bryophyta*. New Delhi: I K International Publishers. ➢ Chopra, R.N. (2005). *Biology of Bryophytes*. India: New Age International Publishers. ➢ Gangulee, H.C. (1978). *Mosses of Eastern India and adjacent regions*. India: Kalyani Publishers. ➢ Pope, R. (2016). *Mosses, Liverworts, and Hornworts*: *A Field Guide to Common Bryophytes of the Northeast*. Ithaca, NY: Comstock Publishing Associates. ➢ Schofield, W. B. (2001). *Introduction to Biology* (Reprint ed.). Caldwell, New Jersey: The Blackburn Press. **Suggested e-Resources:** ➢ **Bryophytes: Identification, Ecology** https://openlibrary.org/subjects/bryophytes ➢ **Bryophytes: General account, classification and structure** http://nsdl.niscair.res.in/jspui/bitstream/123456789/150/1/BRYOPHYTES%20.pdf		

			➢ **Bryophytes: Ecology** https://digitalcommons.mtu.edu/bryophyte-ecology/ ➢ **Bryophyte: Phylogenetic classification** http://bryophytes.plant.siu.edu/class.html		
4)	**BOT 516** Bryology-II	After successful completion of the course, students should be able to: • know the various advances in the field of bryology • know the modern trends in bryology • carry on their research in India and abroad • find opportunities as researchers in various institutes and universities	**Section A** Comparative morphological and anatomical studies of gametophytes and sporophytes in various orders of the class Anthocerotopsida: • Anthocerotaceae - *Anthoceros*, *Folioceros* • Notothyladaceae - *Notothylas*, *Phaeoceros* • Dendrocerotaceae - *Dendroceros*, *Megaceros* • Origin, evolution, fossil history, phylogeny of principal classes: Bryopsida, Hepaticopsida and Anthocerotopsida. **Section B** • Ecology - habitat diversity, growth forms, growth factors. • Role of bryophytes in pollution monitoring, geobotanical prospecting, horticultural uses, economic importance. • Spore diversity, dispersal mechanism and their germination. • Moss protonema, protonemal differentiation and bud induction. **Section C** • Ecological aspects of bryophytes: Bryophytes in relation to nutrient cycling, water restoration, bryophytes associations • Ethnobryology • Molecular Bryology	No change in the existing syllabus	

			• Phytochemicals from bryophytes • Horticultural uses of bryophytes. **Suggested Books:** ➢ Alam, A. (2015). *Text book of Bryophyta*. New Delhi: I K International Publishers. ➢ Chopra, R.N. (2005). *Biology of Bryophytes*. India: New Age International Publishers. ➢ Gangulee, H.C. (1978). *Mosses of Eastern India and adjacent regions*. Kalyani Publishers, India. ➢ Pope, R. (2016). *Mosses, Liverworts, and Hornworts: A Field Guide to Common Bryophytes of the Northeast*. Ithaca, NY: Comstock Publishing Associates. ➢ Rashid, A. (1998). *An Introduction to Bryophyta*. India: Vikas Publishing, ➢ Schofield, W. B. (2001). *Introduction to Biology* (Reprint edition). The Blackburn Press. ➢ Udar, R. (1978). *Bryology in India*. Chronica Botanica Company. **Suggested e-Resources:** ➢ **Bryophyta: Classification** http://bryophytes.plant.siu.edu/class.html ➢ **Bryophyta: Phylogenetic classification** https://bryology.uconn.edu/classification/ ➢ **Bryophyta: Conventional classification** https://www.google.com/search?client=firefox-b&q=recent+classification%3A+liverworts ➢ **Bryophytes: Overall account** https://openlibrary.org/subjects/bryophytes ➢ **Bryophyta: Cryptogamic account** http://nsdl.niscair.res.in/jspui/bitstream/123456789		

			/150/1/BRYOPHYTES%20.pdf ➢ **Bryophyta: Ecology** https://digitalcommons.mtu.edu/bryophyte-ecology/		
5)	**BOT** 513 Angiosperm Taxonomy and Systematics-I	After successful completion of the course, students should be able to: • understand methods and principles of plant classification and nomenclature • learning representative plant families and genera of flowering plants will also help students to identify the plants • learn the embryology, biosystematics, bryodiversity and conservation methods of economically important plants	**Section A** • Systematics: Outline of classification of Angiosperms; Hutchinson, Takhtajan, Cronquist, merits and demerits. • Botanical nomenclature: International code of Botanic Nomenclature; ICBN, principles, Rules and recommendations; priority; typification; Rules of effective and valid publications; retention and choice of names. • Taxonomic features, systematic phylogeny and economic importance of families: Magnoliaceae, Capparidaceae, Combretaceae, Rosaceae, Amaranthaceae, Asteraceae, Apocynaceae, Asclepiadaceae, Convolvulaceae, Scrophulariaceae, Acanthaceae, Bignoniaceae, Lamiaceae, Verbenaceae, Polygonaceae, Euphorbiaceae, Orchidacae, Zingiberaceae, Araceae, Cyperaceae and Poaceae. • Numerical taxonomy: Aims and objectives, characters and attributes, OTUs, coding, cluster analysis, merits and demerits. • Chemotaxonomy: Role of phytochemicals (non-protein amino acids, alkaloids, betalins, cynogenic glucosides, silica, gypsum, raphides, glucosinolate, flavonoids, terpenoids) in taxonomy. • Embryology in relation to taxonomy. **Section B**	No change in the syllabus	

			• Molecular approaches to plant taxonomy: Application of DNA markers in angiosperm taxonomy; molecular phylogeny. • Self incompatibility: Structural and biochemical aspects; methods to overcome incompatibility – mixed pollination, bud pollination; intra -ovarian pollination, *in vitro* pollination. • Experimental embryology: Haploid production; diploidization of haploids, importance of haploids; embyro culture; culture of differentiated and mature embryos; role of natural plant extracts and growth hormones; embryo-nurse endosperm transplantation; culturing of embryonal segments; practical aspects of embryo culture. **Section C** • Biosystematics principles, practice, limitations and scope, phenotypic plasticity, epigenetics. • Biodiversity: general concept, values, isolation and assessment of Genetic Diversity. • Distribution of endemic plant families in the southern hemisphere of the globe. • Conservation: Principles, categories of threatened plants (IUCN), strategies of conservation, Red Data Book. • Botanical Survey of India, its contribution and functions. • Molecular markers in taxonomy and phylogenetic analysis: Nuclear ribosomal DNA, Chloroplast DNA and Mitochondrial DNA. **Suggested Books:** ➢ Graf, A. B. (2010). *Flora of India.* Rajat		

			Publications, India. ➢ Hoorn, C., Perrigo, A., & Antonelli, A. (2018). *Mountains, Climate and Biodiversity: A comprehensive and up-to-date synthesis for students and researchers*. Wiley Science Publishers, USA. ➢ Judd, W.S., & Campbell, C.S. (2007). *Plant Systematics Aphyllogenetic Approach.* Sinarue Publication, New York. ➢ Naik, V.N. (1988). *Taxonomy of Angiosperms*. New Delhi: Tata Mc-Graw Hill Publishing Co. ➢ Rathod, M.M. (2016). *Floristic Ecology and Phytogeography*. Chandralok Prakashan**,** Kanpur, India **Suggested e-Resources:** ➢ **General account of angiosperms**: http://www.nhptv.org/natureworks/nwep14f.htm ➢ **Angiosperm-Life tree** http://tolweb.org/Angiosperms ➢ **Angiosperms: Classification and Reproduction** https://www.toppr.com/guides/biology/plant-kingdom/angiosperms/ ➢ **Angiosperms: Phylogeny** http://www.mobot.org/MOBOT/research/APweb/ ➢ **Angiosperms: APG system of classification** https://academic.oup.com/botlinnean/article/181/1/1/2416499		
6)	**BOT 514** Angiosperms Taxonomy and Systematics-	After successful completion of the course, students should be able to: • describe the evolution by natural selection and other	**Section A** • Plant taxonomy through ages in India: Major contributions of W. Roxburgh, N. Wallich, J.D. Hooker, C. B. Clarke, G. King and K.P. Biswas. Current status of Botanical Survey of India (B.S.I),	No change in the syllabus	

	II	causes • get knowledge about the nature of "species" and can compare contrasting concepts of species • describe binomial nomenclature and use scientific names of species correctly • list levels of the Linnaean hierarchical classification system and use it properly • discuss advantages and disadvantages of the Linnaean system describe systematics • correctly interpret phylogenetic trees and explain their construction	Central National Herbarium (CAL): role in systematic study in India. Acharya Jagadish Chandra Bose Indian Botanic Garden (AJCBIBG) & National Botanical Research Institute (NBRI): activities in relation to taxonomic studies and conservation. • Taxonomic Literature: Categories, brief concept with examples. • Floristic regions of the world (Takhtajan, 1987); Floristic Composition of India: description and composition of Himalayan, Peninsular and Desert vegetation. Biodiversity Act, Role of National Biodiversity Authority (NBA) in biodiversity management; CBD and environmental protocols. **Section B** • Latest changes, addition and alteration in International Code of Botanical Nomenclature (ICBN); Valid Publication: provision of new taxa (Genus); Nomenclature of Hybrid Plants; Nomenclature of Cultivated Plants (ICNCP). • Evolutionary concepts: monophyly, paraphyly, polyphyly, plesiomorphy, apomorphy, anagenesis, stasigenesis, cladogenesis, homology, analogy, homoplasy, parallelism and convergence, synapomorphy and symplesiomorphy. • Modern trends in Taxonomy: Nodal Anatomy: structure, types, evolution and applications. • Palynotaxonomy: pollen structure, types and evolution of pollen grains, applications. Serology, Ultra structures. **Section C**		

			• Biodiversity: components, levels, values, Hotspots and conservation. • Concept of Phytogeography: Endemism, Plant migration, Disjunction, Vicariance, Phytochorionomy (Brief introduction). • Major Phytochona of the World and India. • Ministry of Environment and Forest, India **Suggested Books:** ➢ Graf, A. B. (2010). *Flora of India*. India: Rajat Publications. ➢ Hoorn, C., Perrigo, A. & Antonelli, A. (2018). *Mountains, Climate and Biodiversity: A comprehensive and up-to-date synthesis for students and researchers*. USA: Wiley Science Publishers. ➢ Judd, W.S. & Campbell, C.S. (2007). *Plant Systematics: A phylogenetic Approach*. New York: Sinarue Publication. ➢ Rathod, M.M. (2016). *Floristic Ecology and Phytogeography*. Kanpur, India: Chandralok Prakashan. **Suggested e-Resources:** ➢ **IUCN Red List** https://www.iucnredlist.org/ ➢ **Angiosperms: Herbarium resources** http://apps.kew.org/herbcat/gotoWhatIsHerbarium.do ➢ **Angiosperms: Herbarium techniques** https://herbarium.duke.edu/about/what-is-a-herbarium ➢ **International Code of Botanical Nomenclature**		

			https://www.iapt-taxon.org/icbn/main.htm ➢ **Biodiversity**: https://www.greenfacts.org/en/biodiversity/l-3/1-define-biodiversity.htm ➢ **Conservation of Biodiversity**: http://enviroeducation.com/resources/biodiversity-academic-requirements-professional-outlook ➢ **Angiosperms: Playnotaxonomy** https://openlibrary.org/subjects/palynotaxonomy		
7)	**BT 521:** Plant Biotechnology	After successful completion of the course, students should be able to: • demonstrate principles for development of various stress resistant plants • development of transgenic plants for disease resistance, abiotic stress (drought and salinity) tolerance and molecular markers • understand various techniques used in plant biotechnology	**Section A** • Introduction, examples of current use of plant biotechnology. • Development of pathogen resistant plants (virus & insect resistance). • Development of plants of improved seed quality; Artificial seeds. • Development of plants resistant to environmental stress and herbicides. • Future outlook. **Section-B** • Immobilization of cells. • Direct gene delivery methods. • Vector based gene delivery methods: *Agrobacterium* mediated, Ti plasmid based vectors, viral vectors. • Chloroplast engineering: Advantages of transplastomics, applications in production of biopharmaceuticals, introduction of agronomic traits, *viz*. disease resistance, herbicide resistance, salt and drought resistance; phytoremediation etc. • Biotechnology of biological nitrogen fixation: *nif*	No change in the existing syllabus	

			genes. **Section-C** • Production of metabolites; metabolic engineering and industrial products: Overview of plant secondary metabolites; control mechanisms and manipulation of phenyl propanoids and shikimate pathways; general strategy to regulate the production of plant cell products. • Biotransformation using plant cells. • Cryobiology of plant cell cultures. • Edible vaccines. • Molecular markers - hybridization and PCR based markers RFLP, RAPD, STS, SSR, AFLP, SNP markers. **Suggested Books:** ➢ Chawla, H.S. (2009). *Plant Biotechnology* (3rded.). New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd. ➢ Murphy, D. (2007). *Plant Breeding and Biotechnology: Societal Context and the Future of Agriculture* (1sted.). UK: Cambridge University Press. ➢ Peter, K.V., & Keshavachandran, R. (2008). Plant Biotechnology: Methods in Tissue Culture and Gene Transfer. India: Universities Press. ➢ Singh, B.D. (2011). *Plant Biotechnology* (2nded.). New Delhi, India: Kalyani Publisher. ➢ Singh, B.S. (2007). *Fundamentals of Plant Biotechnology*. New Delhi, India: Satish Serial Publishing House. ➢ Slater, A. (2008). *Plant Biotechnology: The*		

			Genetic Manipulation of Plants (2nd ed.). Oxford, UK: Oxford Publisher. **Suggested e- Resources:** ➢ **Chloroplast Biotechnology** https://onlinelibrary.wiley.com/page/journal/14677652/homepage/chloroplast_biotechnology_special_issue.htm ➢ **Plant transformation technologies** http://repository.ias.ac.in/57240/1/23-pub.pdf ➢ **Abiotic stress and transgenics** http://repository.ias.ac.in/89833/1/1-pub.pdf		
8)	**BT 524: Advanced Plant Biotechnology**	After successful completion of the course, students should be able to: • gain advance knowledge in plant biotechnology and their applications in crop improvement, large scale production of plant metabolites • they are able to get practical insight of techniques • they can go further in plant biotechnology research	**Section A** • Molecular Pharming - concept of plants as Biofactories, production of industrial enzymes and Pharmaceutically important compounds. • Heavy metal toxicity in plants, metal hyperaccumulation & resistance mechanisms. • Concept of Phytoremediation and its applications. • Bioremediation of inorganic (Metals and radionucloides) and organics (TCE/petroleum hydrocarbons/solvents/explosives etc.) in the environment. **Section B** • The improvement of crop yield and quality; • The genetic manipulation of fruit ripening. • Genetic modifications of ethylene biosynthesis and ethylene based fruit sensor; • Golden Rice. • Role of phytohormones in improving the yield of oil seed crops. • CRISPER-CAS and marker free technology.	No change in the existing syllabus	

			Section C • Production of bio-fuels from algal and plant based biomass. • Regulation of abiotic and biotic stress responses by plant hormones. • Nanobiotechnology in Plant research: Effect of different nanomaterials and nanoparticles on Plant. • The Regulation of GM crops and products and the current status of the GM crops. • Intellectual Property in Agriculture Biotechnology. • The future of Plant Biotechnology. **Suggested Books:** ➢ Ahmed, P (2017). Oil seeds Crops. Wiley Publication. ➢ Evans, G. M. & Furlong, J. C. (2011), *Environmental Biotechnology: Theory and Applications*, Wiley Publishers. ➢ Kumar, A. (2008) *Recent advances in plant biotechnology and its applications*. New Delhi: I.K. International Pub. ➢ Oksman-Caldentey, & Kirsi-Marja. (2014). *Plant biotechnology and transgenic plants*. Marcel Dekker. ➢ Prasad, R (2018) Mycoremediation and Environmental sustainability, Springer Publication ➢ Slater, A. Scott, N.W. & MR Fowler. (2014). *Plant bio technology* (2nd ed.). Oxford University Press. ➢ Stewart C. Neal (2018) Plant Biotechnology and Genetics Wiley Publications. **Suggested e- Resources:**		

			➢ **Book Oil Seed crops** https://onlinelibrary.wiley.com/doi/book/10.1002/9781119048800 ➢ **Plant environment interactions** http://fmipa.umri.ac.id/wp-content/uploads/2016/03/Frantisek_Baluska_Plant-Environment_InteractionsBookFi.org_.pdf ➢ **Biotechnology for crop improvement** https://nptel.ac.in/courses/102103013/pdf/mod6.pdf https://www.intechopen.com/books/plants-for-the-future/molecular-farming-in-plants		
9)	Bio Physics-I	After successful completion of the course, students should be able to: • understand the concepts of physical principles in the biomolecular systems • know properties and conformations of biomolecules • understand the interaction between physics and biology	**Section A** • Introduction: Brief introduction to all aspects of Biology, cellular automata, Conway's Game of life. • Cell structure and function: Cell theory, cell membrane and transport, membranous organelles, Non-membranous organelles, Nuclear components and major cell types, viruses. • Molecules in the cell: carbohydrates, lipids, proteins and nucleic acids, their structure and function. • Code of life: Central dogma, DNA replication, transcription and translation. • Energy in life forms: Cellular Respiration, Glycolysis, Krebs cycle, Electron transport chain, ATP calculation, Photosynthesis, C4 pathway. **Section B** • Intermolecular interactions: Covalent interactions, disulphide bonds, van der Waals interactions, bond	No change in the existing syllabus	

			angles and torsions. Role of hydrogen bonding and hydrophobic interaction in biomolecular structures. Examples of α-helices and β-sheets in proteins, Watson-Crick pairs in DNA, stacking interactions in DNA and RNA. • Protein Conformation: Conformational properties of polypeptides, Ramachandran plot, Helical parameters and conformation, organization as secondary and super secondary structures in proteins, domains and motifs. Protein folding in vivo and in vitro of globular proteins, basic idea. **Section C** • Molecular Mechanics: Force field equation, Lennard Jones Potential, Potential energysurface, Z-matrix, Molecular modeling, Energy minimization techniques, Exhaustive search method, steepest descent and conjugate gradient methods, Molecular dynamics simulation, Verlet algorithm and simulated annealing protocol. • Experimental techniques used to determine biomolecular structure: • Principles and application of UV-visible, circular dichroism and fluorescence spectroscopy. • Case studies on Helix to coil transitions, melting curves in proteins and DNA structures. X-ray crystallography of biomolecules: Obtaining single crystals of biomolecules, Single crystal data collection, Determination of point group, space group from symmetry of diffraction patterns, deducing cell parameters, interpretation of intensity data, Calculation of electron density,		

			Solving the phase problem, Structure validation. **Suggested Books:** ➢ Cantor, C. R., & Schimmel, P. R. (1980). *Biophysical Chemistry: Part III: The Behavior Of Biological Macromolecules*. Macmillan. ➢ Jensen, J. H. (2010). *Molecular Modeling Basics*. CRC Press. ➢ Nelson, P. (2004). *Biological Physics*. New York: WH Freeman. ➢ Schlick, T. (2010). *Molecular modeling and Simulation: An Interdisciplinary Guide: An Interdisciplinary Guide* (Vol. 21). Springer Science & Business Media. ➢ Tuszynski, J. A. &Kurzynski, M. (2003). *Introduction to molecular biophysics*. CRC press. ➢ Van Holde, K. E. J. W. *Principles of Physical Biochemistry*/Kensal E. Van Holde, W. Curtis Johnson, P. Shing Ho. ➢ Voet, D., Voet, J. G. & Pratt, C. W. (2013). *Fundamentals of Biochemistry: Life At The Molecular Level* (No. 577.1 VOE). Hoboken: Wiley. **Suggested e-Resources:** ➢ **Non-Conventional Energy Systems** https://nptel.ac.in/syllabus/1021 ➢ **Quantum-mechanics of molecular structure** https://bit.ly/2SoEqof https://bit.ly/2SoEqof		
10)	PHY 533: Bio Physics-II	After successful completion of the course, students should	**Section A** • Physics of macromolecules: Biological polymers,	No change in the existing syllabus	

		be able to: • understand the concepts of physical principles in the biomolecular systems • know Properties and conformations of biomolecules • understand the interaction between physics and biology	modeling polymers as elasticity models, Random walk model, radius of gyration, freely jointed chain, calculation of the distribution of end-to-end distances, statistical segment, persistence length, relation to characteristic ratio, worm like chain, behavior of chain dimension, DNA Elasticity, Application of Porod-Kraty model to DNA. • Protein folding: Anfinsen's thermodynamic hypothesis, Case study: Ribonuclease A, renaturation and denaturation, mechanism of disulphide exchange, determinants of protein folding, Levinthal's paradox, classical view of protein folding, the hydrophobic collapse, Energy landscape theory, Protein Folding problem as a NP-hard problem. **Section B** • Self assembly and membrane equilibria: Self assembly in miscelles as monolayers and bilayers, Thermodynamics of miscelle formation, co-operativity, packing parameter, Tanford's free energy model, Packing model, influence of tail packing, Fluid mosaic model, Langmuir adsorption model. • Electrical conduction in the nervous system: Structure of the neuron, Hodgkin-Huxley model and generation of action potential, Nernst relation in membrane potentials, Donnan equilibrium, ion pumping, voltage gating. Transport in cells: Diffusion, Fick's law, cells with sources, low Reynolds-number, friction in fluids, Transport across cells - osmosis.		

			Section C • Blood flow: Blood as non-Newtonian fluid, Blood flow models, Navier Stokes equation, Dissipative particle dynamics, Erythrocyte model, elastic model. • Energy in muscle: Cytoskeleton, Muscle Contraction, biopolymers of the cytoskeleton, Tubulin, microtubules, associated protein, micro filaments, actin and Myosin. Molecular motors, Kinesin and Dyenin. Sliding filament model of contraction, ATP and muscle contraction, stochastic model of contraction. • Radiation Physics: Dosimetery, Photon interaction coefficients, Relations between exposure, Kerma and absorbed dose, Measurement of exposure, Bragg-Gray Cavity theory, determination of absorbed dose in a medium, radiotherapy, geometrical factors, specification of dose ratios, nuclear medicine. **Suggested Books:** ➢ Cantor, C. R., & Schimmel, P. R. (1980). *Biophysical chemistry: Part III: the behavior of biological macromolecules*. Macmillan. ➢ Jensen, J. H. (2010). *Molecular modeling basics*. CRC Press. ➢ Nelson, P. (2004). *Biological physics*. New York: WH Freeman. ➢ Schlick, T. (2010). *Molecular modeling and simulation: an interdisciplinary guide: an interdisciplinary guide* (Vol. 21). Springer Science		

			& Business Media. ➢ Smith, F. A. (2000). *A primer in applied radiation physics*. World Scientific Publishing Company. ➢ Tuszynski, J. A., & Kurzynski, M. (2003). *Introduction to molecular biophysics*. CRC press. ➢ Van Holde, K. E., Johnson, W. C., & Ho, P. S. (2006). Principles of physical biochemistry. ➢ Voet, D., Voet, J. G., & Pratt, C. W. (2013). *Fundamentals of biochemistry: life at the molecular level* (No. 577.1 VOE). Hoboken: Wiley. **Suggested e-Resources:** https://www.coursera.org/learn/dynamicalmodeling?specialization=systems-biology		
11)	**ENVS 402**: Ecology and Environment	After successful completion of the course, students should be able to: • describe the interaction of organisms with their environment • identify the various threats to biodiversity • explain the concept of biomes • describe the various biogeochemical cycles	**Section A** **Introduction to Environment** • Concept of Environment, Factors of the environment: Physiographic, Climatic, Edaphic, Biotic and Anthropogenic. • Bio Geochemical Cycles: The Carbon cycle, the Oxygen cycle, the Nitrogen cycle, The Hydrological cycle. **Section B** **Concept of Ecology, Ecosystem and Biomes** • Concept of Ecosystem: With special reference to desert, forest and aquatic ecosystem. Food chain, Food web & succession. Ecological Pyramids and their types. • Energy flow in ecosystem, Concepts of Biomes. Major biomes of the world: Tropical forest,	No change in the existing syllabus	

			Temperate forest, Grassland and Tundra. **Section C** **Environmental Pollution and its Effect** • Environmental pollution-Pollutants and sources: • Water pollution, Soil pollution, Air pollution and, Noise pollution. • Green House Effect, Global warming • Biodiversity: Threats and Conservation. **Suggested Books:** ➢ Atkinson, Raw, M. (2007). *Biogeography*. Philip Allan Updates. ➢ Gautam, A. (2007). *Environmental Geography*. Allahabad, India: Sharda Pustak Bhawan. ➢ Huggett, R. J. (1998). *Fundamental of Biogeography*. London, UK: Routledge. ➢ Kayastha, S.L. & Kumra, V.K. (1986). *Environmental Studies*. Varanasi, India: Tara Book Agency. ➢ Mathur, H.S. (1998). *Essentials of Biogeography*. Jaipur, India: Pointer. ➢ Mehtani, S. & Sinha, A. (2010). *Biogeography*. Commonwealth. ➢ Odum, E. P. (1975). *Ecology*. Lanham, MD:Rowman and Littlefield. ➢ Odum, E.P. (1968). *Fundamentals of Ecology*. London, UK:W.B. Sanders Company ➢ Saxena, H. M. (1999). *Environmental Geography*. Jaipur, India: Rawat. ➢ Saxena, H. M. (2000). *Environmental Management*. Jaipur, India: Rawat. **Suggested e-Resources:**		

			➢ **Environment and Ecology, IIT Delhi** https://nptel.ac.in/courses/122102006/16 E**cology and Environment, IIT Madras,** https://swayam.gov.in/courses/4905-july-2018-ecology-and-environment		
12)	ENVS 502 Biodiversity and Conservation	After successful completion of the course, students should be able to: • explain importance of biological diversity • describe major threats to biodiversity • recognize and implement the various methods of biodiversity conservation with co-existence of various environmental pressures • identify different geographical biodiversity hotspots and mega-diversity centers	**Section A** • Introduction to biodiversity concepts, significance, magnitude and distribution. • Biodiversity trends, diversity gradients and related hypotheses methods for monitoring biodiversity trends. • Threats to biodiversity, major causes, extinction's, vulnerability of species to extinction, IUCN threat categories, Red data book. **Section B** • Principles of biodiversity conservation *Ex situ* and *In situ* methods of conservation, Genetical and evolutionary principles in conservation. Conservation of biological diversity and its significance- source of food, medicine, raw material, aesthetic, cultural and ecosystem services. • Concepts, distribution and importance of Hot spots. • Strategies for sustainable exploitation of biodiversity. **Section C** • Conservation efforts in India, Endangered flora & fauna of India. • Ethnobotany in India and ethnomedicinal plants.	No change in the existing syllabus	

			• Wildlife conservation in India- Project Tiger, Project crocodile, silent valley controversy. • Conservation of Himalayan, Gangetic ecosystems. **Suggested Books**: ➢ Kumar, U. &Asija, M.J. (2007). *Biodiversity – Principles and Conservation* (2nded.). Jodhpur, India: Agrobios. ➢ Mishra, R. (1968). *Ecology Workbook* (2nd ed.). Calcutta, India: Oxford and IBH. ➢ Odum, E.P. (1983). *Basic Ecology* (2nd ed.). Philadelphia,PA: Holt-Saunders International. ➢ Odum, E.P. (2004). *Fundamentals of Ecology*. Dehradun, India: Natraj. ➢ Singh, M.P., Singh, J.K., Mohanka, R., & Sah, R.B. (2007). *Forest Environment and Biodiversity (*2nded.*)*. New Delhi, India: Daya. ➢ Sinha, B.N. (1990). *Ecosystem Degradation in India*. New Delhi, India: Ashish. ➢ Tewari, D.N. (1994) *Biodiversity and Forest Genetic Resources*. Dehradun, India: International Book. **Suggested e-resources**: ➢ **Aquatic Biodiversity and Environmental Pollution, IISc, Bangalore** https://nptel.ac.in/courses/120108002/16 ➢ **Wildlife Conservation, Indira Gandhi National Forest Academy, Dehradun** https://nptel.ac.in/noc/individual_course.php?id=noc18-bt26		
	Proposed Reading Elective-I & II to be offered in IV Semester				common with Applied

					Microbiology and Biotechnology for Sem III and IV, Bioscience Sem IV
1)	**BT 529R: Drug Discovery**	After successful completion of the course, students should be able to: • understand basics of R&D in drug discovery and should be able to apply knowledge gained in respective fields of pharmaceutical industry • understand the role of synthetic chemistry in the development of pharmaceutical agents; and the modification of chemical structures to develop new drug molecules • have an advanced understanding of the chemical structure of a pharmaceutical agent and determine the chemical group/s responsible for a given biological effect • demonstrate a basic understanding of pharmacogenomics and bioinformatics as it relates	Modern drug discovery involves the identification of a target or drug lead using different techniques including molecular modeling, combinatorial libraries and high-throughput screening (HTS). Rational drug design is based on the understanding of the three-dimensional structures and physicochemical properties of drugs and receptors. Knowledge of molecular mechanisms, molecular dynamics simulations and homology modeling is necessary for studying drug/receptor interactions. The different conformational sampling techniques, fitness functions used in molecular docking and computational receptor-based and ligand-based drug design approaches are mostly used to design compounds with improved biological activity in rational drug design. Quantitative drug design using QSAR models are used to correlate structural molecular properties (descriptors) with functions (i.e. physicochemical properties, biological activities, toxicity, etc.) of the compounds. Understanding the structure activity relationship between the 3D structure of a molecule and its biological activity may act as the basis for the prediction of compounds with improved biological activities. Different bio-analytical assays (LC/MS/MS, GC/MS and ELISA) could be developed further in support of *in vitro* and *in vivo* studies. Understanding the principles as well as an early characterization of drug toxicity, adsorption, distribution, metabolism and excretion (ADME) along with drug-drug interactions,	No change in the existing syllabus	

		to drug design and discovery • develop an understanding of drug targets as a recognition site for pharmaceutical agents; how the chemical structure of a substance influences interaction with a drug target; and the identification of new drug targets for future drug discovery	plasma protein binding assays and metabolite profile studies helps in eliminating compounds with unacceptable pharmacokinetic characteristics, which is critical to successful drug discovery programs. **Suggested Books:** ➢ Dastmalchi, S. *et. al.* (2016). *Methods and Algorithms for Molecular Docking-Based Drug Design and Discovery*. IGI Global. ➢ Krogsgaard-Larsen *et. al.* (2016). *Textbook of Drug Design and Discovery*. 5th Edition. CRC Press. ➢ Rahman, A. U., Caldwell, G. W. & Choudhary, M. I. (2007). *Frontiers in Drug Design and Discovery.* Bentham Science publishers Limited. ➢ Satyanarayanajois, S. D. (2011). *Drug Design and Discovery: Methods and Protocols*. Humana Press. **Suggested e- Resources:** ➢ **Drug Discovery** https://bit.ly/2tCqdtE ➢ **Peptide therapeutics** https://www.sciencedirect.com/science/article/pii/S1359644614003997 ➢ **Bio-analytical techniques** https://www.pharmatutor.org/articles/bioanalytical-techniques-overview		
2)	**BT 531R: Human Genetics and Diseases**	After successful completion of the course, students should be able to: • understand hereditary and molecular genetics with a strong human disease perspective	Since the rediscovery of Mendel's work in 1900, investigations on the genetic nature of human traits have gained significant importance. Understanding the genetic basis behind human disease is one of the most important reasons to study human chromosome structure, human karyotype, banding techniques, chromosome identification and nomenclature (ISCN)**.**	No change in the existing syllabus	

		• describe genetic abnormalities underlying human disease and disorders • develop interest in biomedical research, genetic counseling, medicine, and clinical genetics	Classical genetics has considerable importance in constructing genetic hypothesis from pedigree data analysis in monogenetic traits, autosomal dominant, autosomal recessive, sex linked dominant, sex linked recessive and sex influenced traits. The impact of consanguinity in causing sex linked anomalies (haemophilia, colour blindness and Duchenne Muscular Dystrophy) has been observed in human population. Current knowledge on genetic variations across populations is applied to study human health and diseases which include chromosomal disorders, structural and numerical chromosomal anomalies (Klinefelter syndrome, Down's syndrome, Turner syndrome, Achondroplasia), inborn errors of metabolism (Phenylketonuria (PKU), Alkaptonuria, Albinism, Galactosemia), haemoglobinopathies, Thalassemia syndromes, multifactorial disorders (diabetes, schizophrenia, huntington disease). Medical genetics involves ethical issues therefore serious discussion is required for prenatal/adult diagnosis of genetic disorders, medical ethics, risks and benefits, informed consent and right of choice. **Suggested Books:** ➢ Pasternak J. Fitzgerald. (1999). *An introduction to Human Molecular Genetics-Mechanism of Inherited Diseases*. Science Press. ➢ Strachan T. & Read. A. (2011). *Human Molecular Genetics* (4th ed.). Garland Science. ➢ Thompson and Thompson. (2007). *Genetics in Medicine (*7th Ed.).Saunders. **Suggested e- Resources** ➢ **Chromosome identification and nomenclature**		

			(ISCN) http://www.cydas.org/Resources/ISCN_Discussion.html ➢ **Pedigree data analysis** https://learn.genetics.utah.edu/content/disorders/ ➢ **Genetic disorders** https://www.genome.gov/10001204/specific-genetic-disorders/ ➢ **Prenatal/ adult diagnosis of genetic disorders, medical ethics** https://www.michiganallianceforfamilies.org/all/#sectionD		
3)	**BT534R: Intellectual Property Rights**	After successful completion of the course, students should be able to: • understand the concept of IPR and its types • describe the steps for patenting • discuss the role of WTO and WIPO on IPR	Intellectual property rights (IPR) have an old history and are very relevant for economic development. Various types of IPR (patents, trademarks, copyright & related rights, industrial design, traditional knowledge, geographical indications) are recognized with specific uses. There is currently an emergence of specific IP pertaining to plants and animals (UPOV, Plant Breeder's rights and plant variety protection and farmers rights act, patent protection of plant and animal inventions (WTO) and Law on the protection of New plant varieties and animal breeds (WIPO)). It is important to know about types of patent applications and the process of patenting with special emphasis to India. The role of WTO (GATT and TRIPS) and WIPO in implementation of IPR is significant as is understanding the relevance of Patent Cooperation Treaty (PCT) in patenting. IPR also are associated with certain ethical dilemma and there are some interesting case studies which highlight its relevance.	No change in the existing syllabus	

			Suggested Books: ➢ Goel D. & Parashar S. (2013). *IPR, Biosafety and Bioethics* (1st ed.) Pearson Education India. ➢ Pandey, N. & Dharni, K. (2014). *Intellectual Property Rights.* PHI Learning. ➢ Ramakrishna, B. & Kumar, A. (2017). *Fundamentals of Intellectual Property Rights: For Students, Industrialist and Patent Lawyers* (1st ed.). Notion Press. ➢ Sateesh, M.K. (2008). *Bioethics and Biosafety*. I.K. International Publishing House. **Suggested e-resources:** ➢ **World Trade Organisation** http://www.wto.org ➢ **World Intellectual Property Organisation** http://www.wipo.int ➢ **International Union for the Protection of New Varieties of Plants** http://www.upov.int ➢ **National Portal of India** http://www.archive.india.gov.in		
4)	**BT 535R: Medical Microbiology**	After successful completion of the course, students should be able to: • identify various bacterial, fungal, viral and protozoan diseases and their epidemiology • understand the relevance of emerging and reemerging diseases	Medical Microbiology describes the cause, transmission, epidemiology, pathogenesis, symptoms, diagnosis and treatment of various bacterial (tuberculosis, typhoid, leprosy), fungal (superficial, subcutaneous, systemic mycosis), protozoan (Malaria, amoebiasis) and viral (AIDS, Influenza, measles) diseases. Currently, it is necessary to understand the impact of emerging and remerging diseases (cholera, dengue, multidrug resistant tuberculosis, H5N1 avian influenza, drug resistant malaria, chikungunya) on human health. Global assessment for various diseases	No change in the existing syllabus	

			also shows an increasing trend of nosocomial infections and opportunistic infections which cause significant mortality and health concerns. **Suggested Books:** ➢ Brooks, G.F., Carroll, K.C., Butel, J.S., Morse, S.A. & Mietzner, T.A. (2013) Jawetz, Melnick and Adelberg's Medical Microbiology (26thed.). US: Lange Medical Books, McGraw-Hill. ➢ Madigan, M., Martinko, J., Stahl, D. & Clark, D. (2010). *Brock Biology of Microorganisms* (13thed.). UK: Pearson Education. ➢ Pelczar Jr., M.J., Chan, E.C.S. & Krieg, N.R. (2011). *Microbiology*. New York, USA:Tata McGraw-Hill. **Suggested e- resources:** ➢ **Emerging Diseases** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3701702/ **Epidemiology** https://bit.ly/2SUmzum ➢ **Nosocomial Infections** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3470069/		
5)	**BT 538R: Molecular Plant Breeding**	After successful completion of the course, students should be able to: • understand strategies and applications of plant breeding technologies • gain knowledge of DNA based molecular markers	Plant breeding study involves breeding methods for self and cross pollinated crops. There are several limitations of conventional breeding. Thus, there is need to have a better breeding approaches to overcome this limitation. Development of molecular markers (RFLP, RAPD, SSRs, ISSRs, SNPs), construction of molecular maps and linkage analysis, mapping populations for QTLs using molecular markers play an important role in plant breeding. In	No change in the existing syllabus	

		for marker assisted selection (MAS), QTL mapping and markers traits association • gain knowledge of different molecular markers for improving crop productivity • plan a research career in the area of plant biotechnology	order to develop potential plant having better qualities, Marker Assisted Selection (MAS) is also a viable approach which can be done by using selection of traits and markers, trait association, marker assisted backcrossing and recurrent selection, marker assisted hybrid breeding and marker assisted improved varieties/germplasm. **Suggested Books:** ➢ Chawla, H. S. (2000). *Introduction to Plant Biotechnology*. USA: Science Publishers. ➢ Glick, B.R., Pasternak, J.J. & Patten C.L. (2010). *Molecular Biotechnology: Principles and Applications of Recombinant DNA* (4th ed.). American Society for Microbiology. ➢ Nicholl, D.S.T. (2008). *An introduction to Genetic Engineering* (3rd ed). Cambridge: Cambridge University Press. ➢ Primrose, S.B., Twyman R.H. & Old R.W. (2001). *Principles of Gene Manipulation* (6th ed.). Wiley-Blackwell. ➢ Slater, A., Scott, N. & Fowler, M. (2008). *Plant Biotechnology: The Genetic Manipulation of Plants* (2nd ed.). UK: Oxford University Press. ➢ Watson, J.D., Gilman, M., Witkowski J. & Zoller, M. (1992). *Recombinant DNA* (2nd ed.). W. H. Freeman publisher. **Suggested e- Resources:** ➢ **Plant breeding** https://nptel.ac.in/courses/102103013/pdf/mod6.pdf ➢ **Molecular marker** https://bit.ly/2XmNm0M		

			➢ **Gene mapping in plant** https://bit.ly/2TaegKm		
6)	**BT539R: Protein Engineering**	After successful completion of the course, students should be able to: • analyse structure and construction of proteins by computer-based methods • describe structure and classification of proteins • analyse and compare the amino acid sequence and structure of proteins, and relate this information to the function of proteins • explain how proteins can be used for different industrial and academic purposes such as structure determination, organic synthesis and drug design • plan and carry out activity measurements of isolated proteins and characterize their purity and stability	An introduction to protein engineering for developing proteins with desired functions. Various methods (rational design and directed evolution) of protein engineering are employed to manipulate the different features or characteristics (affinity, specificity and stability etc) of proteins. Engineering various physicochemical and biological properties (stability to changes in parameters as pH, temperature, amino acid sequence and aggregation propensities etc) of the proteins could be important in their use as protein drugs and/or catalysts in bioreactors. The insight into the fundamental understanding of the mechanisms and forces (Van der waals, electrostatic, hydrogen bonding, weakly polar interactions, and hydrophobic effects), by which protein stabilizes, will help in the formulation of protein based pharmaceuticals. Protein engineering with site-specifically incorporation of unnatural or non-canonical amino acids has been used to improve protein function for medical and industrial applications. Different computational approaches (sequence and 3D structure analysis, data mining, Ramachandran map etc) to protein engineering would help to address the requirements in order to find amino acid sequences that will optimize a desired property (physicochemical property and/or biological function) of a protein. Determination of the physicochemical properties of proteins using various spectroscopic methods (Far-UV and Near-UV CD, Fluorescence, UV absorbance and Optical rotatory dispersion) would further support the drug	No change in the existing syllabus	

			development process. Yeast surface display (YSD)has become a valuable protein engineering tool for modifying the affinity, specificity, and stability of antibodies, as well as other proteins. YSD could be successfully used for protein epitope mapping, identification of protein-protein interactions, and uses of displayed proteins in industry and medicine. Developing vaccines and peptidomimetics will further allow the investigators to identify novel therapeutic leads for numerous unmet clinical needs. **Suggested Books:** ➢ Cleland, J. L. & Craik, C. S. (2006). *Protein Engineering, Principles and Practice*, Vol 7. Springer Netherlands. ➢ Creighton, T. E. (1997). *Protein Structure: a Practical Approach*, 2nd Edition. Oxford University press. ➢ Kyte, J. (2006). *Structure in Protein Chemistry*, 2nd Edition. Garland publishers. ➢ Mueller, K., & Arndt, K. (2006). *Protein Engineering Protocols*, 1st Edition. Humana Press. ➢ Robertson, D., & Noel, J. P. (2004). *Protein Engineering Methods in Enzymology*, Vol 388. Elsevier Academic Press. ➢ Walsh, G. (2014). *Proteins: biochemistry and biotechnology*, Second edition. Chichester, West Sussex: Wiley Blackwell. ➢ Williamson, M. P. (2012). *How proteins Work*. New York: Garland Science. **Suggested e- Resources:** ➢ **Protein Engineering** https://nptel.ac.in/courses/102103017/pdf/lecture%		

			2022.pdf ➢ **Conformational stability of proteins** https://bit.ly/2y85mid ➢ **Protein Engineering with Non-Natural Amino Acids** https://library.umac.mo/ebooks/b2805488x.pdf		

* Matter in contrast (black background & white letters) is shifted to some other units, and material brought as a result of shift is also in contrast.
# Matter in square brackets, bold, italic and crossed is deleted.
@ Proposed added materials are shaded in grey.

Annexure -III

Department of Bioscience and Biotechnology, Banasthali Vidyapith

M.Sc. Bioinformatics (Online and Regular - to be implemented for students admitted from session 2021-22**)**

Existing						**Proposed**					
	M.Sc. Bioinformatics IstSem	**L**	**T**	**P**	**C**		**M.Sc. Bioinformatics IstSem**	**L**	**T**	**P**	**C**
BIO 407	Cell & Molecular Biology **(**c.w.– MSc. BTI Sm)	4	0	0	4	BIO 407	Cell & Molecular Biology	4	0	0	4
						BIO418	Biochemistry	4	0	0	4
BIO 426	Structural Biology	4	0	0	4						
CS 443	Fundamentals of Computer and Programming	2	0	0	2	CS	Fundamentals of Computer and Programming	4	0	0	4
CS 443L	Fundamentals of Computer and Programming Lab	0	0	4	2						
MATH421	Introductory Mathematics	4	0	0	4		Mathematics and Statistics-I	4	0	0	4
BIN 406	Biological Databases	4	0	0	4	BIN	Biological databases and Management systems	4	0	0	4
BIO 419L	~~Bioscience Lab I (c.w.– MSc BT I Sm)~~	0	0	12	6	BIN L	*In Silico* Laboratory – I (C programming, Biol. Databases and DBMS)	0	0	12	6
	Total				**26**		**Total**	**20**	**0**	**12**	**26**

Existing						**Proposed**					
	M.Sc. Bioinformatics IIndSem	**L**	**T**	**P**	**C**		**M.Sc. Bioinformatics IIndSem**	**L**	**T**	**P**	**C**
BIN 404	Algorithms in Computational Biology	4	0	0	4	BIN	Algorithms in Computational Biology	4	0	0	4
BIN 407	Sequence analysis and Phylogenetics	4	0	0	4	BIN	Sequence analysis and Phylogenetics	4	0	0	4
CS 446	Programming with Perl and R	4	0	0	4	CS	Programming with Perl and R	2	0	0	2
CS 446L	~~Programming with Perl and R Lab~~	0	0	8	4		Mathematics and Statistics II	2	0	0	2
BT 408	~~Genetic Engineering (c.w.– MSc,AMBT, BT, Biosci II Sem)~~	4	0	0	4	BIN	Omics Bioinformatics	4	0	0	4
CS 418	~~Database Management System~~	4	0	0	4		Biophysics and Structural Bioinformatics	4	0	0	4
CS 418L	~~Database Management System Lab~~	0	0	4	2	BIN L	*In Silico* Laboratory – II (Perl and R, SQAP, BSB, NGS)	0	0	12	6
	Total				**26**		**Total**	**20**	**0**	**12**	**26**

Existing						Proposed					
	M.Sc. Bioinformatics Sem. III	**L**	**T**	**P**	**C**		**M.Sc. Bioinformatics Sem. III**	**L**	**T**	**P**	**C**
BIN 511	Biomolecular Modeling and Computational Drug Design	4	0	0	4	BIN	Biomolecular Modeling and Simulation	4	0	0	4
BIN 511L	Biomolecular Modeling and Computational Drug Design Lab	0	0	8	4						
BT 545	~~Genomics and Proteomics (c.w.- M.Sc. BT III Sem)~~	4	0	0	4						
CS 538	Python Programming	4	0	0	4	CS	Python Programming	4	0	0	4
CS 538L	~~Python Programming Lab~~	0	0	4	2						
						BIN	Network and Systems Biology	4	0	0	4
	Discipline Elective	4	0	0	4		Discipline Elective	4	0	0	4
	Open Elective	4	0	0	4		Open Elective	4	0	0	4
						BIN L	*In Silico* Laboratory – III (Python programming, BMS, CADD)	0	0	12	6
	Total	**20**	**0**	**12**	**26**		**Total**	**20**	**0**	**12**	**26**
List of Electives (Existing)						**List of Electives (Proposed)**					
BIN507	Mining and Warehousing of Biological Data	4	0	0	4	BIN507	Mining and Warehousing of Biological Data	4	0	0	4
CS 512	Cloud Computing	4	0	0	4	CS 512	Cloud Computing	4	0	0	4
CS 530	Neural Networks	4	0	0	4	CS 530	Neural Networks	4	0	0	4
BIO 503	Fundamentals of Bio-entrepreneurship **(**c.w.- MSc AMBT, BT III Sem)	4	0	0	4	BIO 503	Fundamentals of Bio-entrepreneurship **(**c.w.- MSc AMBT, BT III Sem)	4	0	0	4
BIN 514	~~RNA Structure Function and Transcriptomics~~	4	0	0	4		RNA Bioinformatics	4	0	0	4
BIN 513	~~Systems Biology~~	4	0	0	4		Computational Drug Discovery	4	0	0	4

	Existing						Proposed				
	M.Sc. Bioinformatics Sem. IV	**L**	**T**	**P**	**C**		**M.Sc. Bioinformatics Sem. IV**	**L**	**T**	**P**	**C**
BIN 512D	Dissertation	0	0	48	24	BIN 512D	Dissertation	0	0	48	24
	Reading Elective	0	0	0	2		Reading Elective	0	0	0	2
Total		**0**	**0**	**48**	**26**	**Total**		**0**	**0**	**48**	**26**
List of Reading Elective						**List of Reading Elective**					
BIN 601R	Chemo-informatics	0	0	0	2	BIN 601R	Chemo-informatics	0	0	0	2
BIN 602R	Immuno-informatics	0	0	0	2	BIN 602R	Immuno-informatics	0	0	0	2
BT 531R	Human Genetics and Diseases	0	0	0	2	BT 531R	Human Genetics and Diseases	0	0	0	2
BT 529R	Drug Discovery	0	0	0	2	BT 529R	Drug Discovery	0	0	0	2
BT 539R	Protein Engineering	0	0	0	2	BT 539R	Protein Engineering	0	0	0	2

or

Project Mode

	Proposed				
	M.Sc. Bioinformatics 2nd Year (III and IV Semester)	**L**	**T**	**P**	**C**
New Code/	Dissertation/ Project	0	0	96	48
	Reading Elective-I	0	0	4	2
	Reading Elective-II	0	0	4	2
Total		**0**	**0**	**104**	**52**
List of Reading Elective					
BIN 601R	Chemo-informatics	0	0	4	2
BIN 602R	Immuno-informatics	0	0	4	2
BT 531R	Human Genetics and Diseases	0	0	4	2
BT 529R	Drug Discovery	0	0	4	2
BT 539R	Protein Engineering	0	0	4	2

Comparative Table: M.Sc. Bioinformatics: Existing and Modified syllabus, Suggested Books and Suggested E-Resources

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
	BIO 407: Cell and Molecular Biology (c.w.– M.Sc. BT/ AMBT /Bot/ Zoo I Sem BIO407)	After successful completion of the course, students should be able to: • Understand membrane transport and cell signalling mechanisms. • Develop comprehensive understanding of endo-membrane system. • Understand molecular mechanisms of prokaryotes and eukaryotes	**Cell & Molecular Biology** **Section-A** • Molecular structure and function of plasma membrane; Transport of ions and macromolecules; Pumps, carriers and channels; Membrane carbohydrates and their significance in cellular recognition; Cellular junctions and adhesions. • Endocytosis and exocytosis, clathrin coated vesicles, SNARE proteins. • Cell to cell signalling: autocrine, paracrine and endocrine stimulation. • Signaling via G-protein linked cellsurface receptors, adenylatecyclase system, inositol phosphate pathway, role of Ca^{2+} ions. • Signaling via enzyme-linked surface receptors, tyrosine kinases. • Steroid receptors. **Section-B** • Protein sorting and targeting: Signal hypothesis, SRP, SRP Receptor, ER Resident proteins, ER chaperone proteins and their functions, glycosylation of proteins in ER. • Golgi apparatus, role in protein glycosylation and transport.	**Cell & Molecular Biology** **Section-A** • Molecular structure and function of plasma membrane; Transport of ions and macromolecules; Pumps, carriers and channels; Membrane carbohydrates and their significance in cellular recognition; Cellular junctions and adhesions. • Endocytosis and exocytosis, clathrin coated vesicles, SNARE proteins. • Cell to cell signalling: autocrine, paracrine and endocrine stimulation. • Signaling via G-protein linked cellsurface receptors, adenylatecyclase system, inositol phosphate pathway, role of Ca^{2+} ions. • Signaling via enzyme-linked surface receptors, tyrosine kinases. • Steroid receptors. **Section-B** • Protein sorting and targeting: Signal hypothesis, SRP, SRP Receptor, ER Resident proteins, ER chaperone proteins and their functions, glycosylation of proteins in ER. • Golgi apparatus, role in protein glycosylation and transport.	1.No change proposed

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			• Lysosomes, intracellular digestion, sorting of lysosomal enzymes in Golgi, lysosomal storage diseases. • Transport of proteins into mitochondria and chloroplasts. • Cell Cycle and its regulation, apoptosis. **Section-C** • Replication of genetic material in prokaryotes and eukaryotes: initiation, elongation and termination; Replication of single stranded circular DNA. • Prokaryotic transcription: Transcription units; RNA polymerase structure and assembly; Promotors; Rho-dependent and Rho-independent termination; Anti-termination. • Eukaryotic transcription: RNA polymerase structure and assembly; RNA polymerase I, II, III; eukaryotic promoters and enhancers; general transcription factors; TATA binding proteins (TBP) and TBP associated factors (TAF). • Post transcriptional modifications: processing of hnRNA, tRNA and rRNA; 5'-Cap formation; 3'-end processing and polyadenylation; Splicing; RNA editing; Nuclear export of mRNA; Catalytic RNA. • Genetic code, IsoacceptingtRNA; Translation: Translation machinery;	• Lysosomes, intracellular digestion, sorting of lysosomal enzymes in Golgi, lysosomal storage diseases. • Transport of proteins into mitochondria and chloroplasts. • Cell Cycle and its regulation, apoptosis. **Section-C** • Replication of genetic material in prokaryotes and eukaryotes: initiation, elongation and termination; Replication of single stranded circular DNA. • Prokaryotic transcription: Transcription units; RNA polymerase structure and assembly; Promotors; Rho-dependent and Rho-independent termination; Anti-termination. • Eukaryotic transcription: RNA polymerase structure and assembly; RNA polymerase I, II, III; eukaryotic promoters and enhancers; general transcription factors; TATA binding proteins (TBP) and TBP associated factors (TAF). • Post transcriptional modifications: processing of hnRNA, tRNA and rRNA; 5'-Cap formation; 3'-end processing and polyadenylation; Splicing; RNA editing; Nuclear export of mRNA; Catalytic RNA. • Genetic code, IsoacceptingtRNA; Translation: Translation machinery;	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			initiation, elongation and termination; Co- and post-translational modifications. **Suggested Books:** ➢ De Robertis, E.D.R., & De Robertis, E.M.F. (2017) *Cell and Molecular Biology*. Lippincott Williams & Wilkins. ➢ Hardin, J., Bertoni, G., & Lewis, K.J. (2011) *Becker's World of the Cell*. Pearson. ➢ Karp, G., Lwasa, J., &Larshall, W. (2015) *Cell and Molecular Biology: Concepts and Experiments*. John Wiley & Sons. ➢ Cooper, G., M., & Hausman, R., E. (2013) *The Cell :A Molecular Approach*. Sinauer Associates ➢ Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretsher, A., Ploegh, H., Amon, A., & Martin, K. C. (2007). *Molecular Cell Biology*. W.H.Freeman& Co Ltd. ➢ Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2007). *Molecular Biology of the Cell*. Garland Science. ➢ Freifelder , D. M. (1986). *Molecular Biology*. Jones & Bartlett Publishers. **Suggested e-Resources:** ➢ **Cell Biology resources**https://www.nature.com/scitable ➢ **Sorting and trafficking of proteins**http://www.vcell.science/project/p	initiation, elongation and termination; Co- and post-translational modifications. **Suggested Books:** ➢ De Robertis, E.D.R., & De Robertis, E.M.F. (2017) *Cell and Molecular Biology*. Lippincott Williams & Wilkins. ➢ Hardin, J., Bertoni, G., & Lewis, K.J. (2011) *Becker's World of the Cell*. Pearson. ➢ Karp, G., Lwasa, J., &Larshall, W. (2015) *Cell and Molecular Biology: Concepts and Experiments*. John Wiley & Sons. ➢ Cooper, G., M., & Hausman, R., E. (2013) *The Cell :A Molecular Approach*. Sinauer Associates ➢ Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretsher, A., Ploegh, H., Amon, A., & Martin, K. C. (2007). *Molecular Cell Biology*. W.H.Freeman& Co Ltd. ➢ Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2007). *Molecular Biology of the Cell*. Garland Science. ➢ Freifelder , D. M. (1986). *Molecular Biology*. Jones & Bartlett Publishers. **Suggested e-Resources:** ➢ **Cell Biology resources**https://www.nature.com/scitable ➢ **Sorting and trafficking of proteins**http://www.vcell.science/project/p	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			roteintrafficking ➢ **RNA editing** study.com/academy/lesson/rna-editing-definition-processes.html	roteintrafficking ➢ **RNA editing** study.com/academy/lesson/rna-editing-definition-processes.html	
	BIO 418 Biochemistry	After successful completion of the course, students should be able to: • understand the structure and role of various biomolecules • identify, assess and explain various biochemical pathways • gain understanding of enzymes and their mechanism of action for use in research and allied ventures		**BIO 418 Biochemistry** **Section-A** • Bioenergetics: First and Second law of thermodynamics, concept of free energy, change in standard free energy. • Carbohydrates: general classification, Polysaccharides: Starch, glycogen, cellulose & chitin. • Glycolysis, Citric acid cycle. Electron transport system in mitochondria & chloroplasts. Oxidative phosphorylation, Photosynthetic phosphorylation, P/O ratio, Uncouplers. **Section-B** • Lipids - glycerophospholipids, sphingolipids, gangliosides, eicosanoids & prostaglandins. • Proteins & amino acids – Zwitterionic properties of amino acids & titration curves. Peptide bonds, disulphide crosslinks, various levels of structuralorganization of proteins. • Ramachandran plot, Alpha-helix, Beta sheet. • Structure function relationship in model proteins like ribonuclease A, haemoglobin and chymotrypsin. • Biosynthesis of purines and pyrimidines, de novo and salvage pathway,	1. This course has to be introduced to gain the fundamental knowledge of biomolecules and their biochemical functions. It is proposed to be offered as common with the "Biochemistry (BIO 418)" course of M.Sc. Biotechnology/ AMBT/ Bioscience.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				Section-C • Introduction to enzymes: Classification of enzymes Nomenclature of enzymes, E.C. Number • Enzyme kinetics (Michaelis – Menten kinetics), importance and determination of Vmax and Km values, L & B plots. • Enzyme inhibition: competitive, non-competitive and un-competitive. • Coenzymes and Isozymes. **Suggested Books**: ➢ Berg, J.M., Tymoczko, J.L., Gatto Jr., G.J. &Stryer, L. (2015). Biochemistry (8th ed.). New York, USA: W. H. Freeman and Company. ➢ Cantor, C.R. & Schimmel, P.R. (1980). Biophysical Chemistry Part I, II & III. New York, USA: W. H. Freeman and Company. ➢ Ferdinand, W. (1976). The Enzyme Molecule. New Jersey, USA: John Wiley & Sons Ltd. ➢ Garrett, R. H. & Grisham, C. M. (2012). Biochemistry (5th ed.). Belmont, USA: Wadsworth Publishing Co Inc. ➢ Nelson, D. L. & Cox, M.M. (2012). Lehninger Principles of Biochemistry (6thed.). New York, USA: W. H. Freeman and Company. ➢ Palmer, T. & Bonner, P. (2014). Enzymes:	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				Biochemistry, Biotechnology and Clinical Chemistry. UK: Woodhead Publishing Limited. ➢ Rodwell, V.W., Bender, D., Botham, K.M., Kenelly, P.J. & Weil., P.A. (2018). Harper's Illustrated Biochemistry (31st ed.). New York, USA: McGraw-Hill Education. ➢ Voet, D. &Voet, J.G. (2010). Biochemistry (4th ed.). New Jersey, USA: Wiley. **Suggested e- Resources:** ➢ Metabolic pathways Biomolecules https://epgp.inflibnet.ac.in/ahl.php?csrno=2 ➢ Mechanism of enzyme action http://www.biologydiscussion.com/enzymes/enzymes-properties-and-mechanism-of-enzyme-action/6145 ➢ E-book for Garrett and Grisham https://bit.ly/2TbDWWR	
	~~**BIO 417:**~~ ~~Structural Biolgy~~	After the successful completion of the course, students should be able to: • understand the biophysical processes working at molecular level. • develop analytical understanding of macromolecular	~~**Structural Biology**~~ ~~**Section A**~~ • ~~Introduction to proteins: Amino acids classification and their physicochemical properties.~~ • ~~Hierarchical organization of protein structures primary, secondary, tertiary and quaternary structure of proteins.~~ • ~~Ramachandran Map. Motifs and domains.~~ • ~~Packing of protein structure Structures of~~	Proposed to be discontinued.	1. This course has been introduced in second semester as "Biophysics and Structural Bioinformatics" including some biophysical principles regarding bio-macromolecular structure.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		folding and interactions.	~~oligomeric proteins and study of interaction interfaces~~ • ~~Base pairing in nucleic acids – Watson-Crick and Hoogstein; geometrical and structural properties of A, B, & Z DNA.~~ • ~~Secondary and Tertiary structures of RNA.~~ **~~Section B~~** • ~~Principles and practices in Centrifugation, Chromatography and Electrophoresis for isolation & purification of biomacromolecules.~~ • ~~Circular Dichroism Spectroscopy.~~ • ~~X-Ray crystallography: Introduction, Bragg's law; Crystal system, Bravais Lattices, Space group, symmetry. Protein crystallization, Phase problem and its solutions. Calculation and analysis of electron density map.~~ • ~~Nuclear magnetic resonance: Introduction, chemical shift, NOE and coupling constant, spin – spin coupling and relaxation; 2D NMR spectroscopy (COSY, NOESY).~~ **~~Section C~~** • ~~Three dimensional structure comparison and classification of proteins (VAST, DALI).~~ • ~~Assignment of protein secondary structural elements; DSSP and STRIDE methods.~~ • ~~Various types of weak interactions and their roles in stabilizing the biomolecular~~		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			structures and their interactions. Macromolecular interactions. • Protein-Protein, Protein – DNA and Protein – Ligand interactions **Suggested Books:** ➢ Cantor, C.R. & Schimmel, P.R. (1980). *Biophysical Chemistry* (1st Ed.). W. H. Freeman. ➢ Nelson, D.L. & Cox, M.M. (2017) *Lehninger's Principles of Biochemistry* (7th Ed.). W.H. Freeman. ➢ Schulz, G.E.& Schirmer, R.H. (1979). *Principles of Protein Structure*. Springer. ➢ Schwede, T. &Peitsch, M. (2008). *Computational Structural Biology: methods and applications*. World Scientific Press. ➢ Wilson, K. & Walker, J. (2010). *Practical Biochemistry* (7th Ed.). Cambridge University Press **Suggested e-Resourses:** ➢ **X-ray crystallography**https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1186895/ ➢ **VAST** ➢ https://structure.ncbi.nlm.nih.gov/Structure/VAST/vast.shtml **DALI**https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2896194/.		
	CS 443: Fundamentals of Computer and	The candidates should be able to:	**Fundamentals of Computer and Programming**	**Fundamentals of Computer and Programming**	1. Keeping in view that most of bioinformatics tools

First Semester

S.No.	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
	Programming	• Understand working of computers. • Gain the knowledge of computer program. • Write simple programs to carry out bioinformatics analyses.	**Section A** • Block diagram of computers, its components and functions. Data representation. • Boolean algebra, Basic defintions and theorems of boolean algebra, logic gates and circuits. Sum of products and product of sums, truth tables and Boolean functions. • History of computer evolution. • Concept of program, programming language, algorithms and flowcharts, compilers, interpreters. **Section B** • Operating Systems: Unix, Linux and Windows. • Basic Utilities commands. Pipe and Filters: Grep, SED, AWK, Shell scripting. • Introduction to HPC systems. • Communication technology; Network basics; LAN, WAN & MAN, Intranet, Wireless, and Internet services. Web Services; WWW, URL. **Section C** ~~• Introduction to MATLAB; understanding the MATLAB environment.~~ ~~• Data types in MATLAB; Local and Global variables in MATLAB.~~ ~~• Programming with MATLAB Relational and Logic operators, Control structure of MATLAB, conditional and Loops; Creating~~	**Section A** Block diagram of computers, its components, and functions. Data representation. Boolean algebra, Basic definitions, and theorems of boolean algebra, logic gates and circuits. Sum of products and product of sums, truth tables and Boolean functions. History of computer evolution. Concept of program, programming language, algorithms and flowcharts, compilers, interpreters. **Section B** Operating Systems: Unix, Linux and Windows. Basic Utilities commands. Pipe and Filters: Grep, SED, AWK, Shell scripting. Introduction to HPC systems. Communication technology; Network basics; LAN, WAN & MAN, Intranet, Wireless, and Internet services. Web Services; WWW, URL. **Section C** Introduction to C programming, Variables and Data Types, Operators and Expressions in C, Compilation, and execution of C programs. Conditional Statements and Loops, Arrays, Strings, Pointers, Function and Program Structure in C, I/O operations, and file processing in C. Writing C programs for Bioinformatics applications	require basic understanding of scientific computing and working of Linux operating systems, this course is being proposed with primary focus on Linux operating systems and scientific computations. 2. Introduction of C programming to enable studentswith programming skills.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			~~user – defined functions and function files.~~ • ~~2D and 3D graph plotting with MATLAB.~~ • ~~Introduction to Bioinformatics Toolbox~~. **Suggested Books:** ➢ Sinha, P.K & Sinha, P. (2016). *Computer Fundamentals* (6th Ed.). BPB publication, New Delhi. ➢ Barret, D.G.(2016). *Linux Pocket Guide* (3rd Ed.). OReilly Media. ➢ Gilat, A. (2012). *MATLAB® An Introduction with Applications* (4rd Ed.). John Wiley and Sons. **Suggested e-Resources:** ➢ **Matlab tutorial** https://www.tutorialspoint.com/matlab/	**Suggested Books:** ➢ Sinha, P.K & Sinha, P. (2016). *Computer Fundamentals* (6th Ed.). BPB publication, New Delhi. ➢ Barret, D.G.(2016). *Linux Pocket Guide* (3rd Ed.). OReilly Media. ➢ E. Balagurusamy (2019). Programming in ANSI C (*8 ed*). *Mc. Graw Hill.*	
	~~**CS 443L:**Fundamentals of Computer and Programming Lab~~	The candidates should be able to: • Write programs to analyze biological and statistical data. • Understand different statistical distributions	~~**Fundamentals of Computer and Programming Lab**~~ ~~1. MatLab working environment.~~ ~~2. Constructing vectors and Matrices.~~ ~~3. Diagrammatic representation of data by : Simple Bar, pie-diagrams, Histogram~~ ~~4. File handling in MatLab.~~ ~~5. Computation of :~~ ~~(i) Range, standard deviation, Mean deviation, Quartile deviation and coefficient of variation.~~ ~~(ii) Combined mean and combined standard deviation.~~ ~~6. Introduction to Bioinformatics Toolbox.~~ ~~7. Fitting of following curves by the method of least square:~~	**Proposed to be discontinued.**	1. Some contents of this paper merged with LaboratoryI

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			~~(i) Straight line~~ ~~(ii) Parabola~~ ~~(iii) Exponential curve~~ ~~(iv) Power Curve~~ ~~8. Computation of coefficient of correlation and rank correlation.~~ ~~9. Fitting of regression lines.~~ ~~10. Probability distributions curves :~~ ~~(i) binomial~~ ~~(ii) Poison and~~ ~~(iii) Normal Distribution.~~ ~~11. Comparative studies of different database file formats: GenBank, FASTA and PIR.~~ ~~12. Survey of various genomic, proteomic and evolutionary tools available at ExPasy server.~~ ~~Study of Databases: Uniprot, Unigene, PDB and KEGG~~		
	Mathematics and Statistics – I	After successful completion the candidates should be able to: • Understand the principles of algebra. • Solve the complex biological problems using calculus methods. • Understand the geometrical	~~**IntroductoryMathematics**~~ **Section A** • Set Theory; Introduction to sets and elements, Universal, and empty sets, subsets. Venn diagrams, Set operations and algebra of sets, ordered sets, cartesian product of sets~~, Classes of sets, power sets and partition. Relations; product sets, equivalence relations, partial ordering relations.~~ ~~• Logarithms Definition and laws regarding product, quotient, power and change of~~	**Mathematics and Statistics – I** **Section A** Set Theory: Introduction to sets and elements, Universal, and empty sets, subsets. Venn diagrams, Set operations and algebra of sets, ordered sets, cartesian product of sets. Relations and functions. Two dimensional and three-dimensional vector, vector algebra, scalar and vector products. Introduction to Matrix: types, Order and transpose of matrix. Operations on matrix; addition, subtraction, multiplication.	1. Mathematics and Statistics are integral part of Bioinformatics. 2. All essential ingredients of mathematics and statistics are being introduced here. 3. Probability theory and probability distributions, measure of central tendency

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		properties. • Develop a basic understanding of statistics and statistical distributions.	~~base.~~ • ~~Introduction to complex numbers; algebra of complex number, modulus and conjugate of a complex number.~~ • Introduction to Matrix: types, Order and transpose of matrix. Operations on matrix; addition, subtraction, multiplication. Associative and distributive laws of matrix, Inverse of Matrix and matrix division; determinant of a matrix, Eigen values and Eigenvectors of matrix. **Section B** • Differential Calculus- Derivative of a function, Concept of limit, Continuity, Differentiation, Maxima and Minima of a function. • ~~Introduction to Partial Differentiation.~~ • Integral Calculus: The Idea of the Integral, The Definite Integrals, Indefinite Integrals, Area under curve. • Trigonometric ratios, De Moivre's theorem. • The general equation of a Straight line, slope of a line, intercepts of a line, Angle between two lines, Intersection of two lines, The general equations of a Circle, Parabola, ~~Ellipse, Hyperbola,~~ Cylinder, Cone and Sphere. **Section C** • Probability theory and probability	Associative and distributive laws of matrix, determinant of a matrix, Inverse of Matrix; Eigen values and Eigenvectors of matrix. Linear mappings in R^2 and R^3. **Section B** Differential Calculus- Concept of limits and continuity, Derivative of a function, Differentiation, Maxima and Minima of a function. Integral Calculus: The Idea of the Integral, The Definite and Indefinite Integrals, Area under curve. Ordinary Differential Equations (First order). **Section C** Measures of central tendency- Mean, Median, Mode. Measures of dispersion- range, mean deviation, variance, standard deviation, skewness, and kurtosis. Bivariate data: Correlation and regression analysis. Probability theory and probability distributions; Concepts of random experiment, sample space and events, definition of probability and some elementary results of probability. Conditional probability and Bayes theorem and its biological applications. **Suggested Readings:** 1. Artin M. (2015) *Algebra* (2nd Ed.). Pearson Education. 2. Aitken, M., Broadhurst, B. &Hladky, S.	and correlation analyses are included here. 4. Repeated terms have been removed.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			distributions; Concepts of random experiment, sample space and events, definition of probability and some elementary results of probability. • Conditional probability and Bayes theorem. • Random variable, probability mass function and probability distribution function, cumulative distribution function, Binomial, Poisson and Normal~~(Gaussian)~~ distribution. Measures of central tendency- Mean, Median, Mode. Measures of dispersion- range, mean deviation, variance, standard deviation, skewness and kurtosis. Bivariate data: Correlation and regression analysis **Suggested Books:** ➢ Artin M. (2015) *Algebra* (2nd Ed.). Pearson Education. ➢ Aitken, M., Broadhurst, B. &Hladky, S. B. (2009). *Mathematics for Biological Scientists*. Garland Science. ➢ Thomas, G.B. (2013). *Thomas Calculus* (12th Ed.) Pearson education. ➢ Spiegel, M.R. & Stephens, L. J. (2014). *Schaum's Outline Statistics* (4th Ed.) McGraw-Hills Education. ➢ Spiegel, M., Schiller, J., Srinivasan, R.A.& Goswami, D. (2017). *Schaum's Outline Probability and Statistic* (3rd Ed.). McGraw-Hills Education.	B. (2009). *Mathematics for Biological Scientists*. Garland Science. 3. Thomas, G.B. (2013). *Thomas Calculus* (12th Ed.) Pearson education. 4. Spiegel, M.R. & Stephens, L. J. (2014). *Schaum's Outline Statistics* (4th Ed.) McGraw-Hills Education.	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
	~~BIN 406:~~~~Biological Database~~	After successful completion of the course the candidates should be able to: • understand the architecture of different sequence and structure database. • mine and analyze the biological information from different database.	**~~Biological Databases~~** **~~Section A~~** • ~~Bioinformatics – Sequence Databases- Primary Databases- GenBank, EMBL, DDBJ.~~ • ~~Composite Databases- UniProt.~~ • ~~Secondary databases – Prosite, ProDom, Pfam, InterPro, gene ontology; sequence file formats:- GenBank, FASTA, PIR, ALN/ClustalW2.~~ • ~~Literature Databases- Open access and open sources, PubMed, PLoS, Biomed Central, NAR databases;~~ • ~~Bioinformatics Resources- NCBI, EBI, ExPASy.~~ **~~Section B~~** • ~~Structure database – Primary structure databases- PDB, NDB, MMDB.~~ • ~~Secondary databases-Structural Classification of Proteins – SCOP, Class Architecture Topology Homology – CATH.~~ • ~~Families of Structurally Similar Proteins – FSSP.~~ • ~~Specialized Databases – Viral genome database-ICTVdb; Microbial genome database-MBGD; Genome browsers- Ensembl, VEGA genome browser, NCBI- NCBI map viewer, KEGG, MIPS, UCSC Genome Browser; Archeal Genomics, Eukaryotic genomes with special reference~~	Proposed to be discontinued.	1. Content are incorporated to a new course “Biological databases and Management systems” including the concepts of DBMS

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			to model organisms-Yeast (SGD), Drosophila (FlyBase), C.elegans (WormBase), Mouse, Human (OMIM / OMIA), plants – Arabidopsis (TAIR). **Section C** • Derived Databases- Catalytic Site Atlas – CSA; Databases of molecular functions /enzymatic catalysis databases – KEGG ENZYME database; • Protein-Protein interaction database – STRING; chemical structure database – Pubchem; gene expression database – GEO, SAGE. • Database search engines Text based search engines (Entrez, DBGET /LinkDB). Sequence similarity based search engines (BLAST and FASTA). Motif based search engines (Scan Prosite and eMOTIF). Structure similarity based search engines (combinatorial extension, VAST and DALI). • Proteomics tools- ExPASy server, EMBOSS. **Suggested Books:** ➢ Baxevanis, A.D. & Ouellette, B.F.F. (2004). *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* (3rd Ed.). John Wiley. ➢ Bosu, O. &Thukral, S.K.(2007). *Bioinformatics: database, tools and algorithms* (1st Ed.). Oxford University		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			~~Press.~~ **~~Suggested e-Resources~~** ➢ **~~NCBI~~** ~~https://www.ncbi.nlm.nih.gov/~~ ➢ **~~EBI~~** ~~https://www.ebi.ac.uk/~~ ➢ **~~UNIPORT~~** ~~https://www.uniprot.org/~~ ➢ **~~EXPASY~~** ~~https://www.expasy.org/~~ ➢ **~~Biomed Central~~** ~~https://www.biomedcentral.com/~~ ➢ **~~Databases Journal~~** ~~https://academic.oup.com/database~~		
	~~BIO 404L:~~ ~~Bioscience Lab-I~~	After successful completion of the course, students should be able to: • Demonstrate use of various tools and techniques for detection and quantification of biomolecules. • Perform various biochemical assays for fats, carbohydrate, protein and enzymes • Demonstrate microbiological	**~~Bioscience Lab-I~~** **~~BIO 404L~~** **~~Analytical Techniques~~** ~~1. Demonstration: Working principle & applications of~~ ~~2. Centrifuges (high speed refrigerated centrifuge & ultracentrifuge),~~ ~~3. Fluorescence microscope.~~ ~~4. Atomic absorption spectrophotometer,~~ ~~5. HPLC, FPLC, GC-MS~~ ~~6. Separation of amino acids by TLC and Paper Chromatography.~~ **~~Cell And Molecular Biology~~** ~~7. Study of different stages of mitosis (onion root tip) and meiosis (onion buds/grasshopper testis) and determine the mitotic index.~~	Proposed to be discontinued	1. Revised syllabus of core Bioinformatics is introduced.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		techniques • Access, retrieve, and analyze nucleotide and protein sequences using bioinformatics tools	~~8. Separation of chloroplast by sucrose density gradient centrifugation~~ ~~**Biochemistry**~~ ~~9. To prepare an Acetic-Na Acetate Buffer and validate the Henderson-Hasselbach equation.~~ ~~10. Extraction of crude enzyme from germinating mung bean seeds.~~ ~~11. Estimation of total protein content by Lowry's method~~ ~~12. Separation of protein by SDS PAGE.~~ ~~13. Estimation of acid phosphatase activity using standard curve of p-nitrophenol.~~ ~~14. Purification of the crude enzyme extract (from Expt. 6) using ammonium sulphate precipitation and ion exchange/ affinity chromatography (demonstration).~~ ~~15. Determination of kinetic properties (K_m and V_{max} values) of acid phosphatase.~~ ~~16. Estimation of total carbohydrates using Anthrone method.~~ ~~17. Estimation of reducing sugar by Nelson-Somogyi method.~~ ~~18. Estimation of fats (cholesterol).~~ ~~**Microbiology**~~ ~~19. Isolation and enumeration of microbes from soil and water.~~ ~~20. Staining of selected bacterial and fungal strains~~ ~~21. Estimation of bacterial growth by turbidometric method.~~		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			22. Antibiotic sensitivity test. 23. Estimation of infectivity titre of a virus sample using Plaque assay **Bioinformatics** 24. Database Search: Use and analysis of BLAST tool for protein and DNA sequences. 25. Molecular Evolution: Multiple sequence alignment and phylogenetic analysis. (Clustal X/ Mega/ Tree View) 26. Structure Prediction: Protein secondary and tertiary structure prediction using online tools. 27. Molecular Visualization: Structural analysis of PDB entries for active and inactive states of protein(Pymol). **Suggested Books:** ➢ Aneja, K.R. (1996). *Experiments in Microbiology, Plant Pathology, Tissue Culture and Mushroom Cultivation* (II Ed.). New Delhi: WishwaPrakashan. ➢ Cappuccino, J. G. & Sherman, N. (2014). *Microbiology – A laboratory manual* (10th ed). Pearson **Suggested e-Resources:** ➢ **Harisha, S. Biotechnology procedures and experiments handbook:**http://site.iugaza.edu.ps/mwhindi/files/BIOTECHNOLOGY-PROCEDURES-AND-EXPERIMENTS-HANDBOOK.pdf		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			➢ ~~**Introduction to Biotechnology :**~~ ~~http://www.austincc.edu/awheeler/Files/BIOL%201414%20Fall%202011/BIOL1414_Lab%20Manual_Fall%202011.pdf~~		
	Biologicaldatabases and Management Systems	After successful completion of the course the candidates should be able to: • Understand the architecture of different sequence and structure database. • Gain the knowledge of database development. • Mine and analyze the biological information from different database.		**Biological databases and Management Systems** **Section A** Bioinformatics Sequence Databases–Primary Databases- GenBank, EMBL, DDBJ. Composite Databases- UniProt. Secondary databases - Prosite, Pfam, InterPro, gene ontology Bioinformatics Resources- NCBI, EBI, ExPASy, EMBOSS. Structure database – Primary structure databases - PDB, NDB, Secondary databases-Structural Classification of Proteins – SCOP, Class Architecture Topology Homology –CATH. Specialized Databases NCBI-Genome Data viewer, KEGG, UCSC Genome Browser, Human (OMIM), plants – Arabidopsis (TAIR). **Section B** Introduction to Database Management Systems (DBMS): DMBS concept, architecture and physical data organization. Database users and data models; schemas and instances; data	New course proposed

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				independence and abstraction. Relational database modelling: concepts, integrity constraints, relational algebra, concept of super key, candidate key, primary key. Introduction to SQL commands. Data modelling using entity relationship (ER) models, mapping constraints, Generalization, aggregation, reducing ER diagrams to tables. **Section C** Database designing: Functional dependencies. Normal forms: first, second, third, BCNF, fourth and fifth. Transaction processing and control: ACID properties, locking techniques, time stamping, optimistic approach and multi-version approach. Management of deadlocks, Query processing and optimization. Distributed database systems. Advanced database topics: temporal database, spatial database, data mining, data warehousing and its applications. Recovery, Integrity and security of Databases. **Suggested Books** ➢ Baxevanis, A.D. & Ouellette, B.F.F. (2004). Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins (3rd Ed.). John Wiley. ➢ Bosu, O. &Thukral, S.K.(2007). Bioinformatics: database, tools and algorithms (1st Ed.). Oxford University	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				Press. ➢ Date, C. J. (1999). *An Introduction to Database Systems*(6th Ed.). Addison Wesley. ➢ Bayross, I. (2003). *SQL, PL/SQL The Programming Language of Oracle* (2nd Ed.). BPB New Delhi. 2003 **Suggested e-Resources:** ➢ NCBI: https://www.ncbi.nlm.nih.gov/ ➢ EBI: https://www.ebi.ac.uk/ ➢ UNIPORT: https://www.uniprot.org/ ➢ EXPASY: https://www.expasy.org/ ➢ Biomed Central: https://www.biomedcentral.com/ ➢ Databases Journal: https://academic.oup.com/database	
	***In Silico* Laboratory – I**	After successful completion of the course the students should be able to: • Work in linux environment • Write simple programs in C. • Create relational databases and Manage databases for		*In Silico* Laboratory – I **Linux exercises:** ➢ Working withlinux general purpose commands. ➢ Utility commands: AWK, SED, GREP etc. **C-Programming** Introduction to variables, and operators. Loops and conditions.	1. New course proposed to replace Lab - 1

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		biological purposes • Access, retrieve, and analyze nucleotide and protein information from different databases		Writing simple programs for bioinformatics. **Biological Databases** ➢ Comparative studies of different database file formats: GenBank, FASTA and PIR. ➢ Survey of various genomic, proteomic and evolutionary tools available at ExPasyserver. ➢ Study of Databases: Uniprot, Unigene, PDB and KEGG **DBMS** ➢ Basic DDL commands (creat, drop, alter) with integrity constraints. ➢ DML and DCL commands (Insert, Update, Delete, Select, Commit, Rollback) ➢ Operators (Arithmatic, Logical, Relational etc.) ➢ Assignment based on DDL and DML with conditions also join (Self join, inner join, outer join, equi join) ➢ Complex queries (Retrieval of data from more than one table)	
Second Semester					
	BIN404: Algorithms in	After successful completion of the	**Section A** Algorithms and Data structures in	**Algorithms in Computational Biology**	1. Repeated terms are removed.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
	Computational Biology	course, students should be able to: • Develop understanding on the efficiency and speed of computer algorithm. • Understand the stochastic process and sampling methods. • Understand the system optimization using computational tools.	Bioinformatics; Algorithms and complexity, Iterative and recursive algorithms, Fast versus slow algorithms, Big-O Notation, Algorithm design and analysis techniques, ~~Greedy Algorithms,Randomized Algorithms,~~ Divide-and-Conquer algorithms, Dynamic programming: Shortest Superstring Problem Searching and Sorting algorithms, Linear and non-linear data structure, Stack and Queues, Linked list.~~,Trees Terminologies, Binary trees, Tree traversal (Pre-order, In-order, post-order)~~. **Section B** ~~Brute Force,~~ , Random Walk (1D & 2D), Markov chain; Hidden markov models – ~~Forward, Backward, Viterbi and Baum Welch algorithm~~. Population dynamics algorithms; Intraspecies, Interspecies, and Pre – Predator (two species Lotka – Voltera). Fibonacci series, golden ratio. ~~Introduction to chaos and fractals; Lorenz equation.~~ Random sampling; Monte Carlo, Metropolis algorithms. Introduction to optimization problem, methods of optimization: Genetic algorithm **Section C** ~~Introduction to optimization problem, methods of optimization:Newton Raphson, Quasi Newton methods,Genetic algorithm, Particle Swarm algorithm and Ant colony optimization.~~ Introduction to data clustering; definitions of distance, similarity, cluster, centre and modes. Measure of distances;	**Section A** Algorithms and Data structures in Bioinformatics; Algorithms and complexity, Iterative and recursive algorithms, fast versus slow algorithms, Big-O Notation, Algorithm design and analysis techniques, Divide-and-Conquer algorithms, Dynamic programming: Shortest Superstring Problem Searching and Sorting algorithms, Linear and non-linear data structure, Stack and Queues, Linked list. **Section B** Random Walk (1D & 2D), Markov chain; Hidden markov models. Population dynamics algorithms; Intraspecies, Interspecies, and Pre – Predator (two species Lotka – Voltera). Fibonacci series, golden ratio. Random sampling; Monte Carlo, Metropolis algorithms. Introduction to optimization problem, methods of optimization: Genetic algorithm **Section C** Introduction to data clustering; definitions of distance, similarity, cluster, centre and modes. Measure of distances; Euclidean, Maximum, Mahalanobis and average. Maximum-Likelihood and Expectation-Maximization Algorithms. Center-based Clustering Algorithms; The k-means Algorithm. Hierarchical Clustering; Agglomerative clustering methods; Single link, complete link,	2. Irrelevant algorithms are being proposed to discontinue.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			Euclidean, Maximum, Mahalanobis and average. Maximum-Likelihood and Expectation-Maximization Algorithms. Center-based Clustering Algorithms; The k-means Algorithm. Hierarchical Clustering; Agglomerative clustering methods; Single link, complete link, group average, centroid, and median methods. **Suggested Books:** 1. Jones, N.C. &Pevzner, P.A. (2000). *An Introduction to Bioinformatics Algorithms*. The MIT Press. 2. Dediu, A. H., Hernández-Quiroz, F., Martín-Vide, C. &Rosenblueth, D.A. (2015). (Eds.)*Algorithms for Computational Biology*. Springer. 3. Baxevanis, A.D., Davison, D.B., Page, R. D. M. & Petsko, G.A. (2004). *Current Protocols in Bioinformatics*. John Wiley & Sons Inc. 4. Gibas, C. &Jambeck, P. (2001). *Developing Bioinformatics Computer Skills*. O'Reilly Media, Inc., 5. Parida, L. (2008). *Pattern Discovery in Bioinformatics: Theory & Algorithms*. Chapman and Hall/CRC. **E-Resources** ➢ **Bio-Informatics:Algorithms and Applications**: https://onlinecourses.nptel.ac.in/noc19_	group average, centroid, and median methods. **Suggested Books:** 1. Jones, N.C. &Pevzner, P.A. (2000). *An Introduction to Bioinformatics Algorithms*. The MIT Press. 2. Dediu, A. H., Hernández-Quiroz, F., Martín-Vide, C. &Rosenblueth, D.A. (2015). (Eds.)*Algorithms for Computational Biology*. Springer. 3. Baxevanis, A.D., Davison, D.B., Page, R. D. M. & Petsko, G.A. (2004). *Current Protocols in Bioinformatics*. John Wiley & Sons Inc. 4. Gibas, C. &Jambeck, P. (2001). *Developing Bioinformatics Computer Skills*. O'Reilly Media, Inc., 5. Parida, L. (2008). *Pattern Discovery in Bioinformatics: Theory & Algorithms*. Chapman and Hall/CRC **E-Resources** ➢ **Bio-Informatics:Algorithms and Applications**: https://onlinecourses.nptel.ac.in/noc19_bt01/preview ➢ **Markovian Processes**: https://www.coursera.org/learn/dna-	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			bt01/preview ➢ **Markovian Processes**: https://www.coursera.org/learn/dna-analysis	analysis	
	BIN 407: Sequence analysis and Phylogeny	After successful completion of the course the candidates should be able to: • Understand the biological sequence analysis. • Identify similar sequences in the database. • Understand the phylogenetic analyses	**Sequence Analysis and Phylogeny** **Section A** • Sequence Analysis – concepts of sequence similarity, Sequence identity vs homology. Definitions of homologues, orthologues, paralogues and xenologues. Basic methods of sequence analysis; Dot plot method, sequence distance calculation (Hamming and Levinshtein), their merits and demerits. Scoring matrices: basic concept and construction of a scoring matrix; PAM and BLOSUM matrix ~~and their derivatives~~. Pairwise sequence alignment: Global and Local alignment algorithms; gap penalties, ends free alignment. Statistical significance of alignment score. **Section B** • Sequence-based database searches: algorithm of BLAST and FASTA and interpretation of results. Algorithms for generation of sequence profiles; profile-based database searches using PSI-BLAST, analysis and interpretation of profile-based searches. Multiple sequence alignments	**Sequence Analysis and Phylogeny** **Section A** Sequence Analysis – concepts of sequence similarity, Sequence identity vs homology. Definitions of homologues, orthologues, paralogues and xenologues. Basic methods of sequence analysis; Dot plot method, sequence distance calculation (Hamming and Levenshtein), their merits and demerits. Scoring matrices: basic concept and construction of a scoring matrix; PAM and BLOSUM matrix. Pairwise sequence alignment: Global and Local alignment algorithms; gap penalties, ends free alignment. Statistical significance of alignment score. **Section B** Sequence-based database searches: algorithm of BLAST and FASTA and interpretation of results. Algorithms for generation of sequence profiles; profile-based database searches using PSI-BLAST, analysis, and interpretation of profile-based searches. Multiple sequence. Algorithm of CLUSTALW and PileUp and their application for sequence analysis.	1. Some repeated and irrelevant terms are removed.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			(~~MSA): the need for MSA. Theory and application of various approaches for MSA; progressive and hierarchical.~~ Algorithm of CLUSTALandPileUp and their application for sequence analysis. **Section C** • The concept of evolutionary tree; types of phylogenetic trees (rooted vs. unrooted trees), Molecular Clock Newick format of tree representation. Introduction to evolutionary models; Jukes Cantor and Kimura two parameter. Algorithms of Phylogenetic Tree Construction: UPGMA, Neighbor-Joining, Maximum Parsimony, Maximum likelihood, and Bayesian Inference. ~~Statistical assessments of phylogenetic methods (Consistency, Efficiency, Robustness, & Computational speed).~~ Evaluation of phylogenetic tree: Bootstrapping~~, Randomized and jack-knifing methods.~~ **Suggested Books:** ➢ Mount, D.W. (2004). *Bioinformatics: Sequence and Genome Analysis*. (2nd Ed.). Cold Spring Harbor Press. ➢ Durbin, R., Eddy, S.R., Anders, K. & Graeme, M (2002). *Biological Sequence Analysis: Probabilistic models of protein and Nucleic acids*. Cambridge University Press.	**Section C** The concept of evolutionary tree; types of phylogenetic trees (rooted vs. unrooted trees), Molecular Clock, Newick format of tree representation. Introduction to evolutionary models; Jukes Cantor and Kimura two parameter. Algorithms of Phylogenetic Tree Construction: UPGMA, Neighbor-Joining, Maximum Parsimony, Maximum likelihood, and Bayesian Inference. Evaluation of phylogenetic tree: Bootstrapping. **Suggested Books:** ➢ Mount, D.W. (2004). *Bioinformatics: Sequence and Genome Analysis*. (2nd Ed.). Cold Spring Harbor Press. ➢ Durbin, R., Eddy, S.R., Anders, K. & Graeme, M (2002). *Biological Sequence Analysis: Probabilistic models of protein and Nucleic acids*. Cambridge University Press. ➢ Nei M. & Kumar, S. (2004). *Molecular Evolution and Phylogenetics*. Oxford University Press **Suggested E Resources** ➢ **Sequence Analysis** ➢ https://www.coursera.org/learn/bioinformatics-methods-1	

First Semester					
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			➢ Nei M. & Kumar, S. (2004). *Molecular Evolution and Phylogenetics*. Oxford University Press **Suggested E Resources** ➢ **Sequence Analysis** https://www.coursera.org/learn/undefined ➢ **Molecular Evolution:** https://www.ebi.ac.uk/training/online/course/introduction-phylogenetics	➢ **Molecular Evolution:** https://www.ebi.ac.uk/training/online/course/introduction-phylogenetics	
	CS 446: Programming with Perl and R	After successful completion of the course the candidates should be able to: • Understand the perl scripting for string manipulations. • Understand using the perl modules. • Understand the environment of R and Bioconductors.	**Programming with Perl and R** **Section A** Perl Data types: Scalar variables, scalar operations and functions, array variables, array representation, array operations and functions, hash variables and its representation, hash functions. Application of hashes to write genetic code and gene expression data. Perl regular expression: Concepts and use of regular expression for biological data. Metacharacters, Pattern-matching, Substitutions, Transliteration, split and join functions. Subroutines and its advantage, arguments, passing data to subroutines. Concept of file handling, opening, rading editing and closing a File. Directory handling: opening reading and closing a directory. **Section B** Bioperl: Introduction to Bioperl and its	**Programming with Perl and R** **Section A** Perl Data types: Scalar variables, scalar operations and functions, array variables, array representation, array operations and functions, hash variables and its representation, hash functions. Application of hashes to write genetic code and gene expression data. Perl regular expression: Concepts and use of regular expression for biological data. Metacharacters, Pattern-matching, Substitutions, Transliteration, split and join functions. Subroutines and its advantage, arguments, passing data to subroutines. Concept of file handling, opening, rading editing and closing a File. Directory handling: opening reading and closing a directory. **Section B**	1. No changes proposed in the content, but the credit of the course has been reduced to two.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			installation. Bioperl architecture: general classes, Sequences -Bio::Seq Class, sequence manipulation, alignments -AlignIO, Analysis - Blast, Databases- Database Classes. Introduction to common gateway interface module (CGI.pm), CGI program in Context, Perl and the Web. Introduction to R language; R Objects and data structures – Variable classes, Vectors and matrices, Data frames and lists, Data sets included in R packages, Summarizing and exploring data, Reading data from external files, Storing data to external files, Creating and storing R workspaces. **Section C** Object Manipulating using R – Mathematical operations (recycling rules, propagation of names, dimensional attributes, NA handling), Basic matrix computation (element-wise multiplication, matrix multiplication, outer product, transpose, eigenvalues, eigenvectors), Textual operations, Basic graphics (high-level plotting, low-level plotting, interacting with graphics). Introduction to Big data in Bioinformatics: Characteristics, data structures and data repositories; exploratory analysis of big data in R environment, Bioconductor, Microarray and next-generation sequencing (NGS) data analysis in R environment. **Suggested Books:**	Bioperl: Introduction to Bioperl and its installation. Bioperl architecture: general classes, Sequences -Bio::Seq Class, sequence manipulation, alignments -AlignIO, Analysis - Blast, Databases- Database Classes. Introduction to common gateway interface module (CGI.pm), CGI program in Context, Perl and the Web. Introduction to R language; R Objects and data structures – Variable classes, Vectors and matrices, Data frames and lists, Data sets included in R packages, Summarizing and exploring data, Reading data from external files, Storing data to external files, Creating and storing R workspaces. **Section C** Object Manipulating using R – Mathematical operations (recycling rules, propagation of names, dimensional attributes, NA handling), Basic matrix computation (element-wise multiplication, matrix multiplication, outer product, transpose, eigenvalues, eigenvectors), Textual operations, Basic graphics (high-level plotting, low-level plotting, interacting with graphics). Introduction to Big data in Bioinformatics: Characteristics, data structures and data repositories; exploratory analysis of big data in R environment, Bioconductor, Microarray and next-generation sequencing (NGS) data	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			➢ Schwartz RL et al.; Learning Perl (2008, 5th Ed.) O'Reilly. ➢ Wall L et al.; Programming Perl (2012, 4th Ed.) O'Reilly. ➢ Gerrard P and Johnson RM.; Mastering Scientific Computing with R (2015), Packt Publishing, UK. ➢ Hahne F. et al.; Bioconductor case studies (2008), Springer. ➢ Lewis PD.;R for Medicine and Biology (2010), Jones and Bartlett Series. **Suggested E Resources** ➢ **Perl Programming** https://www.learn-perl.org/ ➢ **R Programming** https://www.rstudio.com/online-learning/	analysis in R environment. **Suggested Books:** ➢ Schwartz RL et al.; Learning Perl (2008, 5th Ed.) O'Reilly. ➢ Wall L et al.; Programming Perl (2012, 4th Ed.) O'Reilly. ➢ Gerrard P and Johnson RM.; Mastering Scientific Computing with R (2015), Packt Publishing, UK. ➢ Hahne F. et al.; Bioconductor case studies (2008), Springer. ➢ Lewis PD.;R for Medicine and Biology (2010), Jones and Bartlett Series. **Suggested E Resources** ➢ **Perl Programming** https://www.learn-perl.org/ ➢ **R Programming** https://www.rstudio.com/online-learning/	
	Mathematics and Statistics – II	After successful completion the candidates should be able to: • Understand the basics of discrete mathematics. • Solve the complex biological problems using numerical methods. • Understand the Fourier		**Mathematics and Statistics – II** **Section A** The general equation of a Straight line, slope of a line, intercepts of a line, Angle between two lines, Intersection of two lines, The general equations of a Circle, Parabola, Cylinder, Cone and Sphere. Trigonometric ratios, De Moivre's theorem. **Section B** Numerical Methods: Solution of algebraic and transcendental equations, Bisection method, Newton-Raphson method.	1. New course proposedincluding discrete mathematics and statistical theorems, which is essential to understand some advanced algorithms in Bioinformatics.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		Transformations and its applications. • Develop the understanding of statistical analyses and hypothesis testing		Fourier Transformations: Properties of Fourier Transformations, Fourier Transformation of a convolution, Inverse Fourier Transformations. **Section C** Random variable, probability mass function and probability distribution function, cumulative distribution function, Binomial, Poisson and Normal distribution. Hypothesis testing: Significance of a test, P-value, t-test, Analysis of Variance (ANOVA), Chi-square test. **Suggested Readings:** 1. Artin M. (2015) *Algebra* (2nd Ed.). Pearson Education. 2. Aitken, M., Broadhurst, B. &Hladky, S. B. (2009). *Mathematics for Biological Scientists*. Garland Science. 3. Spiegel, M.R. & Stephens, L. J. (2014). *Schaum's Outline Statistics* (4th Ed.) McGraw-Hills Education.	
	OMICS Bioinformatics	After successful completion the candidates should be able to: • Understand the experimental methods available to study the genome		**OMICS Bioinformatics** **Section A** Genomics- Introduction to genomes and genomics; Genetics vs. Genomics. Concepts of Whole Genome Sequencing (WGS) and Whole Exome Sequencing (WES); Structural organization of genomes; Mutations and	1. New course proposed including the concepts of Genomics, Proteomics and Transcriptomics.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		and proteomes. • Develop understanding of computational tools of genomics and proteomics. • Understand the next generation sequencing methods.		polymorphisms. Metagenomics, epigenomics and pharmacogenomics; Large scale genome sequencing strategies. Genome assembly and annotations; Prediction of genes, promoters, splice sites. Variant analyses. Comparative genomics. **Section B** Proteomics- Introduction to proteome and proteomics; protein chemistry vs. proteomics. Analytical techniques of proteomics, working principles of 2D gel electrophoresis, mass spectrometry with their merits and demerits. Mass spectrometers for protein and peptide sequencing. Peptide Mass Fingerprinting: Scoring algorithm for Spectral analysis, Application of SALSA in amino acids - Motif Searching. Protein interaction databases and tools. **Section C** Introduction to Transcriptomics; Genome Wide Gene Expression Analysis, DNA microarray: preparation, analysis of microarray data. Strategies in RNA-Seq technologies. Tissue Specific Transcriptomics and Expression Pattern Analysis. Gene Set Enrichment Analysis. Differential gene expression, correlation of gene expression data to biological process and analysis tools. Transcriptional Regulation of Gene Expression in Prokaryotes and Eukaryotes.	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				Suggested Books: ➢ Brown, S.M. (2015). Next-generation DNA sequencing Informatics (2nd Ed.). Cold Spring Harbor Press. ➢ Liebler, D. C. (2001). Introduction to proteomics tools for the new biology. Humana Press. ➢ Lesk, A.M. (2015). Introduction to Genomics (2nd Ed). Oxford University Press. ➢ Pevsner, J. (2017). Bioinformatics and Functional Genomics (3rd Ed). John Wiley. ➢ Twyman, R.M. (2004). Principles of Proteomics; CBS Publishers. ➢ Thangadurai, D. & Sangeetha, J. (2015). Genomics and Proteomics: Principles, Technologies, and Applications. CRC Press. ➢ Wang, X. (2016). Next-generation sequencing data analysis. CRC Press.	
	Biophysics and Structural Bioinformatics	After successful completion, the candidates should be able to: • Develop analytical understanding of macromolecular folding and interactions. • Gain the knowledge of experimental		**Biophysics and Structural Bioinformatics** **Section A** Introduction to proteins: Amino acids classification and their physicochemical properties. Hierarchical organization of protein structures – primary, secondary, tertiary, and quaternary structure of proteins. Ramachandran Map. Motifs and domains. Packing of protein structure, Structures of oligomeric proteins and study of interaction	1. New Course proposed merging the contents of "BIO 426 Structural Biology" from I semester

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		techniques for protein structure determination. • Explore the macromolecular structure databases		interfaces Base pairing in nucleic acids – Watson-Crick andHoogsteein; geometrical and structural properties of A, B, & Z DNA. **Section B** Principles and practices in Centrifugation, Chromatography and Electrophoresis for isolation & purification of biomacromolecules. Circular Dichroism Spectroscopy. X-Ray crystallography: Introduction, Bragg's law; Crystal system, Bravais Lattices, Space group, symmetry. Protein crystallization, Phase problem and its solutions. Calculation and analysis of electron density map. Nuclear magnetic resonance: Introduction, chemical shift, NOE and coupling constant, spin – spin coupling and relaxation; 2D – NMR spectroscopy (COSY, NOESY). **Section C** Macromolecular packing: non-covalent forces in molecular interactions Useful databases relevant to structural bioinformatics (PDBe, CATH etc.). Three-dimensional structure comparison and classification of proteins (VAST, DALI). Assignment of protein secondary structural elements; DSSP method. Protein secondary structure prediction. RNA Secondary structure prediction.	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				Prediction of binding pockets and channels in proteins. Prediction of protein function from structural similarity. **Suggested Books:** ➢ Cantor, C.R. & Schimmel, P.R. (1980). *Biophysical Chemistry* (1st Ed.). W. H. Freeman. ➢ Nelson, D.L. & Cox, M.M. (2017) *Lehninger's Principles of Biochemistry* (7th Ed.). W.H. Freeman. ➢ Schulz, G.E.& Schirmer, R.H. (1979). *Principles of Protein Structure*. Springer. ➢ Schwede, T. &Peitsch, M. (2008). *Computational Structural Biology: methods and applications*. World Scientific Press. ➢ Wilson, K. & Walker, J. (2010). *Practical Biochemistry* (7th Ed.). Cambridge University Press ➢ Haken H., and Wolf H.C. (2004) Molecular Physics and Elements of Quantum Chemistry. Springer **Suggested e-Resourses:** ➢ **X-ray crystallography**https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1186895/ ➢ **VAST** ➢ https://structure.ncbi.nlm.nih.gov/Structure/VAST/vast.shtml **DALI**https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2896194/	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
	***In Silico* Laboratory – II**	After successful completion the candidates should be able to: • Develop the skills for writing programs for biological data manipulation in Perl. • Develop and use simple Perl modules • Analyze the big data in biology using R • Understand the use of several Bioinformatics tools for sequence and structure analysis		***In Silico* Laboratory – II** **Perl exercises** 1. Use of various arithmetic and logical operators. 2. Programming based on string manipulation (concatenation, splitting etc.) 3. Regular expression and its applications. Use of s/// and tr/// operators. 4. Pattern matching to locate and count motifs in a string. 5. Constructing arrays. addition and removal of elements from array, exploring array. 6. Use hashes in conversion of three letter code to one letter code and proteing translation. 7. Perl subroutines. 8. File handling, reading data from a file writing data to a file and editing a file. 9. Directory handling, make a directory, change present working directory, reading files from a directory. 10. Introduction to Perl modules, construction of simple module **R Exercise** 11. Basic statistical analyses in R. 12. Using R for simple problems of molecular biology. 13. Use of Bioconductor for analyzing biological data. **Sequence Analysis** 14. Demonstration of pair wise and	1. This course is being introduced to provide the core knowledge of biotechnological methods of gene manipulation.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				Multiple sequence analysis. 15. Demonstration of local BLAST and parsing BLAST output. 16. Demonstration of Mega Software for phylogenetic analysis. **Structural Bioinformatics** 17. Molecular visualization tools (Pymol, Chimera, VMD). 18. Protein structure comparison VAST. 19. Analysis of secondary structures using DSSP and STRIDE. 20. RNA secondary structure prediction. **NGS data analysis** 21. Downloading and analyzing FASTQ files. 22. Quality assurance and assembly generation. 23. Variant calling 24. Differential expression analysis and downstream analysis	
	~~CS418:~~ ~~Database Management Systems~~	~~After successful completion of the course the candidates should be able to:~~ • ~~Understand relational database systems~~ • ~~Calling, processing and optimizing the databases.~~ • ~~Mining data from~~	**~~Database Management Systems~~** **~~Section A~~** ~~Introduction: - Data base system concepts, Comparison between traditional file system and DBMS, Database Users, Data models, schemas and instances, Data independence, 3 level architecture of DBMS, Overall data base structure. Data modeling using Entity Relationship Model: - ER model, mapping constraints, Concept of super key, candidate~~	Proposed to discontinue	1. The contents are merged with a new course "Biological databases and Management systems" in I semester.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		~~open access biological databases.~~	~~key, primary key, Generalization, aggregation, reducing ER diagrams to tables. Relational Data Model: concepts, integrity constraints, relational algebra, SQL queries.~~ **~~Section B~~** ~~Data Base design: - Functional Dependency and its types, normal forms: first, second, third and BCNF, multi-valued dependency, fourth normal form, join dependency and fifth normal form. Steps in database design. Transaction processing: Introduction, ACID properties, Concurrency control techniques: Locking techniques, Time stamping, Optimistic approach, Multi-version. Management of deadlocks, Query processing and optimization.~~ **~~Section C~~** ~~Recovery, Integrity and security of Databases. Distributed Database systems: Introduction, Fragmentation, Replication, Transparency, Consistency and Concurrency control, Homogeneous Vs Heterogeneous systems. Advanced topic in databases: temporal database, spatial database, data mining, data warehousing and its applications. Case studies using NCBI, SwissProt and PDB.~~ **~~Suggested Books:~~** ➢ ~~Hanery, K. & Abraham, S. (1997). *Database System Concepts*. New York, Tata Mac- Graw Hill.~~ ➢ ~~Date, C. J. (1999). *An Introduction to*~~		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			~~*Database Systems*(6th Ed.). Addison Wesley.~~ ➢ ~~Hanery, K. & Abraham, S. (1997). *Database System Concepts*. New York, Tata Mac Graw Hill.~~ ➢ ~~Baxevanis, A.D. & Ouellette, B.F.F. (2004). *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* (3rd Ed.). John Wiley.~~		
	~~**CS418:** Database Management Systems lab~~	~~After successful completion of the course the candidates should be able to:~~ • ~~Create relational databases.~~ • ~~Manage databases for biological purposes.~~	~~**Database Management System Lab**~~ 1. ~~Basic DDL commands (creat, drop, alter) with integrity constraints.~~ 2. ~~DML and DCL commands (Insert, Update, Delete, Select, Commit, Rollback)~~ 3. ~~Operators (Arithmatic, Logical, Relational etc.)~~ 4. ~~Assignment based on DDL and DML with conditions also join (Self join, inner join, outer join, equi join)~~ 5. ~~Complex queries (Retrieval of data from more than one table)~~	**Proposed to discontinue**	1. The contents are merged with a new course "*In Silico*Laboratory – I" in I semester.
	~~**CS 446L:** Programming with Perl and R Lab~~	~~After successful completion of the course, students should be able to:~~ • ~~Write the perl programs for string manipulations.~~	~~**Programming with Perl and R Lab**~~ ~~1. Use of various arithmetic and logical operators.~~ ~~2. Programming based on string manipulation (concatenation, splitting etc.)~~	**Proposed to discontinue**	1. The contents are merged with a new course "*In Silico* Laboratory – II" in II semester.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		• Develop and use simple perl modules. • Install and use the Bioconductor packages from R for statistical analyses of biological data.	3. Regular expression and its applications. Use of s/// and tr/// operators. 4. Pattern matching to locate and count motifs in a string. 5. Constructing arrays. addition and removal of elements from array, exploring array. 6. Use hashes in conversion of three letter code to one letter code and proteing translation. 7. Perl subroutines. 8. File handling, reading data from a file writing data to a file and editing a file. 9. Directory handling, make a directory, change present working directory, reading files from a directory. 10. Introduction to Perl modules, construction of simple module 11. Basic statistical analyses in R. 12. Using R for simple problems of molecular biology. 13. Use of Bioconductor for analyzing biological data. **Suggested Books:** □ Wall L et al.; Programming Perl (2012, 4th Ed.) O'Reilly. □ Gerrard P and Johnson RM.; Mastering		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			Scientific Computing with R (2015), Packt Publishing, UK. **Suggested e-Resources:** **Perl Programming**: https://www.learn-perl.org/ **R Programming**: https://www.rstudio.com/online-learning/		
	BT408 Genetic Engineering	Genetic engineering is the core course of modern biotechnology. The students will be well equipped to handle gene manipulation techniques in biotechnology based industries and research institutions. Moreover, this course will also help the students to perform better in competitive examinations also able to take up biological research as well as placement in the relevant biotech industry.	**Genetic Engineering** **Section-A** Basic concepts of DNA structure and properties, restriction enzymes, DNA ligase, Klenow enzyme, T4 DNA polymerase, Polynucleotide kinase, Alkaline phosphatase, Cohesive and blunt end ligation, Linkers, Adapters, Homopolymeric tailing, Labeling of DNA, Nick translation, Random priming, Radioactive and non-radioactive probes, Hybridization techniques, Northern, Southern and Colony Hybridization, Chromatin immunoprecipitation, DNA-Protein Interaction-Electromobility shift assay, DNaseIfootprinting, Methyl interference assay, Isolation of genomic DNA from prokaryotes and eukaryotes, Isolation of Plasmid DNA and Bacteriophage DNA. Isolation of total RNA and mRNA. **Section-B** Plasmids, Bacteriophages, pBR322 and pUC	**Proposed to discontinue**	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			series of vectors, M13 and P2 phage based vectors, High capacity vectors:Cosmids, phagemid, BAC, Animal and Plant virus based cloning vectors, Shuttle vectors, Expression vectors, pMal, GST, pET based vectors, Constructions of libraries, cDNA and genomic libraries, cDNA and genomic cloning, Expression cloning, Jumping and hopping libraries, South western and Far western cloning, Protein protein interactive cloning and Yeast two hybrid system, Phage display. **Section C** Primer designing, Fidelity of thermostable enzymes, Types of PCR- multiplex, nested, reverse transcriptase, real time PCR, touchdown PCR, hot start PCR, colony PCR, in situ PCR, cloning of PCR products, T-vectors, Principles in maximizing gene expression, Gene expression analyses, differential gene expression methods, Introduction of DNA into mammalian cells, transfection techniques. **Suggested Books:** ➢ Old, R. W., Primrose, S. B., & Twyman, R. M. (2001). *Principles of GeneManipulation: an Introduction to Genetic Engineering*. Oxford: Blackwell Scientific Publications ➢ TBrown, T. A. (2006). *Genomes* (3rd ed.). New York: Garland Science Pub ➢ Glick, B.R. & Pattern, C.L. (2017). *Molecular Biotech: Principles and*		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			application of recombinant DNA(5th Ed.).ASM Press. ➢ Reece, R. J. (2004). *Analysis of genes and genome*. John Wiley and sons Ltd. ➢ Green, M. R., & Sambrook, J. (2012). *Molecular Cloning: a Laboratory Manual*. Cold Spring Harbor, NY: Cold Spring Harbor Laboratory Press. **Suggested e-Resources:** **Genetic engineering - Basics, New Applications and Responsibilities -** http://library.umac.mo/ebooks/b28055287.pdf.		
Third Semester					
	BIN 511: Molecular Modeling and Computational Drug Design	After successful completion of the course the candidates should be able to: • Understand the principles of statistical thermodynamics. • Develop understanding of principles of biomolecular modelling and simulations. • Understand the computational	**Biomolecular Modeling and Computational Drug Design** **Section – A** Basic Thermodynamics - The Laws of Thermodynamics, the Maxwell Relations, the Gibbs-Duhem Equation and Extensive Functions, Intensive Functions. Lagrangian Formulation, Hamiltonian Formulation and Canonical Transformations Classical approach to Ensembles: Ensembles and Phase Space. Partition Function: Review of rotational, vibrational and translational partition functions. Application of partition functions to specific heat of solids and chemical equilibrium. **Section – B** Homology modeling, Protein Threading and	Proposed to discontinue	1. The content of this course has been reduced to a new course "Biomolecular Modeling and Simulation"

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		methods for drug designing and development.	~~abinitio methods. Introduction to Molecular mechanics. Optimization of modeled protein 3D structure. Energy minimization (steepest descent, conjugate gradient and Newton-Raphson methods). Molecular dynamics simulation: Equation of motion, integration schemes; Introduction to force fields, its popular variants; Ergodic Hypothesis, Ensembles (Canonical and Micro-Canonical) and their control in MD simulation, periodic boundary conditions and calculation of long range potentials (Particle – Mesh and Ewald summation methods). Potential energy surface: Convergence Criteria, Characterizing Stationary Points, Search for Transition States.~~ **~~Section – C~~** ~~Computational Drug design; Drug likeness: Lipinski's rules, ligand efficiency and lipophilic ligand efficiency. Molecular recognition: affinity determination, intermolecular binding free energy. Ligand based drug design: - pharmacophore, constrained systematic search and genetic algorithm. Structure based drug design: Molecular docking and virtual screening.~~ ~~Introduction to QSPR and QSAR. Molecular descriptors used in QSAR studies: electronic; topological and quantum chemical. QSAR models: Free Wilson and Hansch equation. Statistical methods for QSAR modeling: regression, principle component and partial~~		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			~~least squares analysis. Bioisosteres, Hammet substituent constant.~~ ~~**Suggested Books:**~~ ➢ ~~Cramer, C. (2004) *Essentials of Computational Chemistry* (2nd Ed); John Wiley.~~ ➢ ~~Leach, A. R. (2001). *Molecular Modeling Principles and applications*. Pearson Education.~~ ➢ ~~Thomas G. (2003) Fundamentals of Medicinal Chemistry; John Wiley.~~ ➢ ~~Alvarez J. and Shoichet B. (Ed.) (2004). *Virtual Screening in Drug Discovery*. Taylor and Francis.~~ ➢ ~~Kukol, A. (Ed.) (2015). *Molecular Modeling of Proteins* (2nd Ed.). Springer Nature. Young, D.C. (2009). *Computational Drug Design*. John Wiley.~~ ~~**Suggested e-Resources:**~~ ➢ ~~**Statistical Mechanics**~~ ~~https://onlinecourses.nptel.ac.in/noc19_ph06/preview~~ ➢ ~~**MD Simulation and SBDD**~~ ~~https://nptel.ac.in/courses/103103036/13~~ ~~https://onlinecourses.nptel.ac.in/noc18_bt28/preview~~		
	Biomolecular Modeling and Simulation	After successful completion of the course the candidates should be able to: • Understand the		**Biomolecular Modeling and Simulation** **Section – A** Basic Thermodynamics - The Laws of Thermodynamics, the Maxwell Relations, the	1. New course introduced

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		principles of statistical thermodynamics. • Develop understanding of principles of biomolecular modelling. • Understand the concepts of molecular docking and simulation		Gibbs-Duhem Equation and Extensive Functions, Intensive Functions. Classical approach to Ensembles: Ensembles and Phase Space. Partition Function: Review of rotational, vibrational, and translational partition functions. Application of partition functions to specific heat of solids and chemical equilibrium. **Section – B** Protein 3D structure Modeling: Concept of protein folding comparative (homology), threading and ab-initio methods. Modeling protein – ligand interactions: Concept of molecular docking, its variations, and applications. Introduction to Molecular mechanics: Concept of force fields- united atom and all atom force fields, applications and limitations of force fields. Theoretical water models (explicit and implicit) and their properties. Introduction to Energy minimization. Potential energy surface. **Section – C** Biomolecular Simulations: brief idea of ensembles (NVT, NPT, NVE), concept of ergodicity. Periodic boundary conditions. Molecular dynamics simulations: equation of motion, integration schemes, Maxwell – Boltzmann distribution of velocity. Control of temperature and Pressure during MD. Introduction to Monte Carlo simulations:	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				algorithm and importance in sampling. Applications of molecular simulations in biomolecular conformational sampling and binding free energy estimations (MM-PB/GBSA, LIE and FEP/TI). **Suggested Books:** ➢ Cramer, C. (2004) *Essentials of Computational Chemistry* (2nd Ed); John Wiley. ➢ Leach, A. R. (2001). *Molecular Modeling-Principles and applications*. Pearson Education. ➢ Kukol, A. (Ed.) (2015). *Molecular Modeling of Proteins* (2nd Ed.). Springer Nature. Young, D.C. (2009). *Computational Drug Design*. John Wiley. **E-resources** ➢ Molecular Dynamics on Web (https://mmb.irbbarcelona.org/MDWeb/)	
	CS538: Python	After the successful completion of course the	**Python Programming** **Section A**	**Python Programming**	1. This paper has been revised to fulfill the

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
	Programming	candidates should be able to: • Understand the python programming environment. • Understand using the python libraries. • Learn file and directory handling in python.	Python interpreter and interactive mode; values and types: int, float, boolean, string, and list; variables, expressions, statements, tuple assignment, precedence of operators, comments; modules and functions, function definition and use, flow of execution, parameters and arguments; ~~Illustrative programs: exchange the values of two variables, circulate the values of n variables, distance between two points.~~ **Section B** Conditionals: Boolean values and operators, conditional (if), alternative (if-else), chained conditional (if-elif-else); ~~Iteration: state, while, for, break, continue, pass; Fruitful functions: return values, parameters, local and global scope, function composition, recursion;~~ Strings: string slices, immutability, string functions and methods, string module; Lists as arrays. Illustrative programs: square root, gcd, exponentiation, sum an array of numbers, linear search, binary search. **Section C** ~~Lists: list operations, list slices, list methods, list loop, mutability, aliasing, cloning lists, list parameters; Tuples: tuple assignment, tuple as return value; Dictionaries: operations and methods; advanced list processing – list comprehension; Illustrative programs: selection sort, insertion sort, mergesort, histogram~~. Files and exception: text files, reading and writing	**Section A** Introduction to Python interpreter, interactive mode; built in classes in Python3: int, float, boolean, string, and list; variables, expressions, general purpose operators and their precedence, comments. Conditionals: Boolean values and operators, conditional (if), alternative (if-else), chained conditional (if-elif-else); Iteration: state, while, for, break, continue, pass. Some useful functions in python3. Exception handling in Python3 **Section B** Working with strings in Python; string slices, immutability, string functions and methods, string module; Basic operations on Lists in Python3. Python functions; function definition and in application, flow of execution, parameters, and arguments; modules and packages, modular programming in Python. Introduction to object-oriented programming with Python; Object, Class, Method, Inheritance and Encapsulation. **Section C** Files and directory handling in Python3: working with text files, reading, and writing files. Illustrative programs: word count, copy file. Python in Bioinformatics. Introduction to Biopython; Installation, and applications.	requirements of non-programming background students in biology and Bioinformatics.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			files, format operator; command line arguments, errors and exceptions, handling exceptions, modules, packages; ~~Illustrative programs: word count, copy file.~~ **Suggested Books:** ➢ Sedgewick, R., Wayne, K. &Dondero R. (2015). *Introduction to Programming in Python: An Inter-disciplinary Approach*. Addison – Wesley Professional. ➢ Lambert, K.A. (2011). *Fundamentals of Python: First Programs*, Cengage Learning. ➢ Goodrich, M.T., Tamassia, R. & Goldwasser M.H. (2016). Data structure and Algorithms in Python. Wiley India Pvt.Ltd. ➢ Bassi, S. (2017). *Python for Bioinformatics* (2nd Ed.). Chapman and Hall/ CRC press. **Suggested e-Resources:** ➢ Python tutorials https://www.tutorialspoint.com/execute_python_online.php https://onlinecourses.nptel.ac.in/noc16_cs11/preview	Introduction to sequence objects in biopython. Database access with biopython. Sequence annotation with Biopython. Parsing the BLAST output. Analysis of PDB with biopython. Cluster analysis, phylogeny with Biopython. Graphics in Python. **Suggested Books:** ➢ Sedgewick, R., Wayne, K. &Dondero R. (2015). *Introduction to Programming in Python: An Inter-disciplinary Approach*. Addison – Wesley Professional. ➢ Lambert, K.A. (2011). *Fundamentals of Python: First Programs*, Cengage Learning. ➢ Goodrich, M.T., Tamassia, R. & Goldwasser M.H. (2016). Data structure and Algorithms in Python. Wiley India Pvt.Ltd. ➢ Bassi, S. (2017). *Python for Bioinformatics* (2nd Ed.). Chapman and Hall/ CRC press. **Suggested e-Resources:** ➢ Python tutorials https://www.tutorialspoint.com/execute_python_online.php https://onlinecourses.nptel.ac.in/noc16_cs11/preview	
	~~**BIN 513:**~~ Network and	After the successful completion of course the	**Systems Biology** **Section A**	**Network and Systems Biology** **Section A**	1. Previously, the course "Systems Biology" was

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
	Systems Biology	candidates should be able to: • Understand the different types and properties of biological networks. • Understand using the various databases of biological networks. • Learn to model the metabolic processes.	Introduction to Graph, forest & Network. Parameters of networks: degree of node, degree distribution and power law behavior, shortest path, mean path, clustering coefficient, node centrality and network centrality. Types of networks: random, small world, scale-free networks, and Hierarchical networks. Robustness of a Network: Topological, Functional, and dynamical robustness. **Section B** Introduction to biological networks, properties, and importance of biological networks. Types of biological networks. Protein interaction network, Types of Protein-Protein interactions (PPI): Stable, Transient, Physical, and Genetic interactions. Prediction of Protein-Protein interactions: experimental and computational methods. Databases of biological networks (~~STRING, BioGRID, STITCH and KEEG~~), Designing of network circuitry (CYTOSCAPE), ~~Network layouts.~~ **Section C** Gene Regulatory network: Methods for regulatory network reconstruction, Boolean and Bayesian network model. Multi-layer hierarchical structure of regulatory networks.Metabolic Network, Signaling networks ~~and their identification methods Methods in system Biology:~~ Interaction based method, Construction based methods, and Mechanism based methods. Visual	Introduction to Graph and Network. Parameters of networks: degree of node, degree distribution and power law behaviour, shortest path, mean path, clustering coefficient, node centrality and network centrality. Types of networks: random, small world, scale-free networks, and Hierarchical networks. Robustness of a Network: Topological, Functional, and dynamical robustness. Introduction to mathematical modelling. **Section B** Introduction to biological networks, properties, and importance of biological networks. Types of biological networks. Protein interaction network, Types of Protein-Protein interactions (PPI): Stable, Transient, Physical, and Genetic interactions. Prediction of Protein-Protein interactions: experimental and computational methods. Designing of network circuitry (CYTOSCAPE). **Section C** Gene Regulatory network: Methods for regulatory network reconstruction, Boolean and Bayesian network model. Metabolic Network, Signaling networks modelling and their reconstruction methods. Visual representations and notations for systems biology-Metabolic Pathway visualization and editing software (MyBioNet, MetaViz,	one among the elective courses. Considering its importance, it has now been introduced as compulsory course with a new name and some modifications.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			representations and notations for systems biology, Metabolic Pathway visualization and editing software (MyBioNet, MetaViz, Cytoscape). Future for system Biology. Synthetic biology and artificial gene circuits. **Suggested Books:** ➢ Klipp, E., Liebermeister W., Wierling C., Kowald A. & Herwig R. (2016). *Systems Biology: A Textbook*. Wiley – Blackwell. ➢ Covert, M.W. (2014). *Fundamental of Systems Biology: From Synthetic Circuits to Whole – Cell Models.* CRC press. ➢ Helms, V. (2008). *Principles of Computational Cell Biology*. Wiley – Blackwell. ➢ Panchenko, A. &Przytycka T.M. (Ed.) (2008). *Protein-protein Interactions and Networks: Identification, Computer Analysis, and Prediction*. Springer – Verlag London. ➢ Vadyanathan, S., Harrigan G.G. & Goodacre R. (2005). Metabolome analyses: Strategies for Systems Biology. Springer – Verlag. ➢ Alon, U. (2006). *An Introduction to Systems Biology: Design Principles of Biological Circuits.* Chapman & Hall/CRC, Tailor & Francis. **Suggested e-Resources:** ➢ **Network Biology** https://www.coursera.org/learn/network-	Cytoscape, CellDesigner). Future for systems Biology: Synthetic biology and artificial gene circuitry. **Suggested Books:** ➢ Klipp, E., Liebermeister W., Wierling C., Kowald A. & Herwig R. (2016). *Systems Biology: A Textbook*. Wiley – Blackwell. ➢ Covert, M.W. (2014). *Fundamental of Systems Biology: From Synthetic Circuits to Whole – Cell Models.* CRC press. ➢ Helms, V. (2008). *Principles of Computational Cell Biology*. Wiley – Blackwell. ➢ Panchenko, A. &Przytycka T.M. (Ed.) (2008). *Protein-protein Interactions and Networks: Identification, Computer Analysis, and Prediction*. Springer – Verlag London. ➢ Vadyanathan, S., Harrigan G.G. & Goodacre R. (2005). Metabolome analyses: Strategies for Systems Biology. Springer – Verlag. ➢ Alon, U. (2006). *An Introduction to Systems Biology: Design Principles of Biological Circuits.* Chapman & Hall/CRC, Tailor & Francis. **Suggested e-Resources:**	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			biology ➢ **System Biology** https://www.coursera.org/learn/systems-biology ➢ **Synthetic Biology** https://www.edx.org/course/principles-of-synthetic-biology	➢ **Network Biology** https://www.coursera.org/learn/network-biology ➢ **System Biology** https://www.coursera.org/learn/systems-biology ➢ **Synthetic Biology** https://www.edx.org/course/principles-of-synthetic-biology	
	***In Silico* Laboratory – III**	After the successful completion of course the candidates should be able to: • Write python programs for studying biological samples. • Model the 3D structure of the biomolecules. • Carry out biomolecular interaction studies. • Perform MD simulations to study the biomolecular dynamics.		***In Silico* Laboratory – III** **Python programming** 1. Introduction to variables and various arithmetic & logic operations. 2. Introduction to strings and lists 3. Conditionals and Loops in python. 4. Working with files and directories in python. 5. Working with Molecular biology problems such as transcription, translation, GC island identification. 6. Working with sequence analysis problems such as global alignment, local alignment Parsing Blast output etc. 7. Accessing biological databases with Python. **BMS**	1. New course introduced

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				8. Molecular visualization tool (applications such as molecular interaction, Molecular surface visualization, electrostatics, H-bond calculation etc.) 9. Identification of different structural motifs in proteins.A 10. Analysis of PDB (NMR and X-ray) structures (Quality of structure, analyzing molecular interactions, protein-ligand/protein-protein if any, from PDB). 11. Homology based protein structure prediction. 12. Quality estimation of modeled protein structure (ProCheck, PROSA, Verify 3D, Errat etc.). 13. Contact map based protein structure comparison. 14. Energy minimization based mutational analysis of proteins (using SwissPDB-Viewer). 15. Carry out molecular dynamics simulation. 16. Simple analyses of MD data such RMSF, RDF movie making etc. **CADD** 17. Protein-Ligand docking Autodock and MGLTools and Pharmacophore analysis.	
	~~BIN 511L:~~	After successful	**~~Biomolecular Modeling and Computational~~**	Proposed to discontinue	1. Appropriate contents

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
	~~Molecular Modeling and Computational Drug Design Lab~~	completion of the course the candidates should be able to: • Model the 3D structure of the biomolecules. • Carry out biomolecular interaction studies. • Perform MD simulations to study the biomolecular dynamics.	**~~Drug Design Lab~~** • ~~Molecular visualization tool (applications such as molecular interaction, Molecular surface visualization, electrostatics, H-bond calculation etc.)~~ • ~~Identification of different structural motifs in proteins.A~~ • ~~Analysis of PDB (NMR and X-ray) structures (Quality of structure, analyzing molecular interactions, protein-ligand/protein-protein if any, from PDB).~~ • ~~Homology based protein structure prediction.~~ • ~~Quality estimation of modeled protein structure (ProCheck, PROSA, Verify 3D, Errat etc.).~~ • ~~Contact map based protein structure comparison.~~ • ~~Energy minimization based mutational analysis of proteins (using SwissPDB-Viewer).~~ • ~~Protein-Ligand docking Autodock and MGL Tools and Pharmacophore analysis.~~ • ~~Carry out molecular dynamics simulation.~~ ~~Simple analyses of MD data such RMSF, RDF movie making etc.~~		have been incorporated in *In Silico* Laboratory – III
	~~BT 545:~~ ~~Genomics and Proteomics~~	After successful completion of the course the candidates should be able to:	**~~Genomics and Proteomics~~** **~~Section – A~~** ~~Genomics – Introduction to genome and genomics; genetics vs genomics. DNA~~	**Proposed to discontinue**	1. This course is proposed to discontinue. Appropriate contents have been incorporated in

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		• Understand the experimental methods available to study the genome and proteomes. • Develop understanding of computational tools of genomics and proteomics. • Understand the next generation sequencing methods.	~~microarray; prepration, understanding of microarray data, normalizing microarray data, detecting differential gene expression, correlation of gene expression data to biological process and analysis tools. Gene Expression Omnibus (GEO). Genomics and Metagenomics Large scale genome sequencing strategies. Genome assembly and annotation. Genome databases of Plants, animals and pathogens. Metagenomics: Gene networks: basic concepts, computational model such as Lambda receptor and lac operon. Prediction of genes, promoters, splice sites, regulatory regions: basic principles, application of methods to prokaryotic and eukaryotic genomes.~~ **~~Section – B~~** ~~Proteomics – Introduction to proteome and proteomics; protein chemistry vs proteomics. Analytical techniques of proteomics; working principles of 2D – gel electrophoresis, mass spectrometry with their merits and demerits. Mass spectrometers for protein and peptide sequencing; MALDI – TOF, Electospray Ionization coupled tendem Mass spectrometry.Tendem mass analyzer, triple quadrupole mass analyzer, ion – trap mass analyzer and FT – ion cyclotron resonance MS. Peptide Mass Fingerprinting. Sequencing the protein fragments: Scoring Algorithm for Spetral Analysis. Application of SALSA in~~		a new paper named as: Omics Bioinformatics.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			amino acid – Motif searching. **Section – C** Next Generation sequencing & assembly: Elements of big data analysis, NGS Platforms based on pyrosequencing, sequencing by synthesis, emulsion PCR approach with small magnetic beads and single molecule real time (SMRT) sequencing; Genome assembly algorithms, De-novo assembly algorithms, Sequence Alignment formats: Sequence Alignment/Map (SAM) format, Binary Alignment/Map (BAM) format. Protein function prediction using Machine learning tools: supervised/unsupervised learning, Neural network, SVM. Protein-protein interactions: databases such as STRINGS, DIP, PPI server and tools for analysis of protein-protein interactions **Suggested Books:** ➢ Brown, S.M. (2015). *Next-generation DNA Sequencing Informatics* (2nd Ed.). Cold Spring Harbor Press. ➢ Liebler, D. C. (2001). *Introduction to Proteomics Tools for the New Biology*. Humana Press. ➢ Lesk, A.M. (2015). *Introduction to Genomics* (2nd Ed). Oxford University Press. ➢ Pevsner, J. (2017). *Bioinformatics and Functional Genomics* (3rd Ed). John Wiley. ➢ Twyman, R.M. (2004). *Principles of*		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			Proteomics; CBS Publishers. ➢ Thangadurai, D. & Sangeetha, J. (2015). *Genomics and Proteomics: Principles, Technologies, and Applications*. CRC Press. **Suggested e-Resources:** ➢ **Proteomics** https://nptel.ac.in/courses/102101055/4 ➢ **Genomics** https://edu.t-bio.info/course-category/omics/ https://ocw.mit.edu/courses/biology/7-012-introduction-to-biology-fall-2004/video-lectures/lecture-25-genomics/		
	CS 538L: Python Programming Lab	After the successful completion of course the candidates should be able to: Write python programs for studying biological samples.	**Python Programming Lab** 17. Introduction to variables and various arithmetic & logic operations. 18. Introduction to strings and lists 19. Conditionals and Loops in python. 20. Working with files and directories in python. 21. Working with Molecular biology problems such as transcription, translation, GC island identification. 22. Working with sequence analysis problems such as global alignment, local alignment Parsing Blast output etc. 23. Accessing biological databases with Python.	Proposed to discontinue this course.	Appropriate contents have been incorporated in*In Silico* Laboratory – III

First Semester

S.No.	Course List	Learning Outcome	Existing Syllabus	Suggested Syllabus	Remarks
	~~BIN 514:~~ RNA Structure Function and Transcriptomics	After the successful completion of course the candidates should be able to: • Understand the structure of various non-coding RNAs and their functions • Learn techniques of genome wide expression studies.	**~~RNA Structure Function and Transcriptomics~~** **Section A** The biology, chemistry, structure and function of the RNA molecule in prokaryotic and eukaryotic systems ~~including their viruses~~. Interaction between RNA molecules. Interaction between RNA and proteins. Interaction between RNA and small ligands. The role of RNA in an evolutionary perspective. Description of non coding RNA and their functions and possible mechanism of action. (SnRNA, SnoRNA, siRNA, miRNA, Catelytic RNA and Ribozymes) **Section B** Transcriptome and Transcriptomics; Genome Wide Gene Expression Analysis: Microarrays: experiments to annotation. ~~Expressed sequence tags: EST Genration, EST Clustering importance in gene identification. Serial analysis of gene expression (SAGE), SAGE data and its importance~~. Tools for Transcriptomics and Transcriptome Analysis. **Section C** ~~Database and web tools for ESTs project. Tissue Specific Transcriptomics and Expression Pattern Analysis.~~ Transcriptional Regulation of Gene Expression in Prokaryotes and Eukaryotes~~. The Transcriptome~~ Projects. Impact of Transcriptomics on functional	**RNA Bioinformatics** **Section A** The biology, chemistry, structure, and function of the RNA molecule in prokaryotic and eukaryotic systems. Interaction between RNA molecules. Interaction between RNA and proteins. Interaction between RNA and small ligands. The role of RNA in an evolutionary perspective. Description of non-coding RNA and their functions and possible mechanism of action (SnRNA, SnoRNA, siRNA, miRNA, Catalytic RNA, circular RNA and Ribozymes). **Section B** Transcriptional Regulation of Gene Expression in Prokaryotes and Eukaryotes. Transcriptome and Transcriptomics: Tools for Transcriptomics and Transcriptome Analysis, Genome Wide Gene Expression Analysis - Microarrays: Types of microarrays, microarrays- experiments to annotation. RNA sequencing – principle, workflow, and applications. **Section C** Impact of Transcriptomics on functional genomics, Diseases and drug discovery, Evolutionary analyses, and Pharmaceutical Research. Computational Design of Artificial RNA Molecules for Gene Regulation.	Course discontinued in its present form. 1. The Section A of this course introduces the description of noncoding RNAs which are essential part of genome regulators. 2. Section B and C are adopted from the previously existing course Transcriptomics and Metabolomics, with slight update.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			genomics, Diseases and drug discovery, Evolutionary analyses and Pharmaceutical Research. **Suggested Books:** ➢ Meister G. (2011), *RNA Biology*; Wiley – VCH. ➢ Gesteland, R. F., Cech, T & Atkins, J. (2005). *The RNA World* (3rd Ed.), CSHL – press. ➢ Wu J. (Ed.) (2016),*Transcriptomics and Gene Regulation*; Springer – Nature. ➢ Passos G.A. (Ed.) (2014). *Transcriptomics in Health and Disease*; Springer Publications. **Suggested e-Resources:** ➢ **Genomics 1 - T-BioInfo in Education** https://edu.t-bio.info/course-category/omics/ ➢ **Non coding RNA** https://www.nature.com/collections/sqtqxdnvdz ➢ **Epigenetics** https://www.whatisepigenetics.com/non-coding-rna/	Transcriptome Assembly and Alternative Splicing Analysis. Detection of Post-Transcriptional RNA modifications. **Suggested Books:** ➢ Meister G. (2011), RNA Biology; Wiley – VCH. ➢ Gesteland, R. F., Cech, T & Atkins, J. (2005). The RNA World (3rd Ed.), CSHL – press. ➢ Wu J. (Ed.) (2016), Transcriptomics and Gene Regulation; Springer – Nature.	
	Computational Drug Discovery	After the successful completion of the course the candidates should be able to: • Understand the properties of drug targets and drugs.		**Computational Drug Discovery** **Section – A** Druggable targets: proteins (with examples of enzymes, transcription factors, membrane proteins), RNA and DNA as dug targets. Introduction to drug-target interactions: Forces	1. New course proposed.

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		• Learn the process of CADD. • Gain the knowledge of QSAR modeling.		stabilizing drug – target interactions. Drug metabolism: Pharmacokinetics (ADME) and pharmocodynamics of drug action, bioavailability of drugs. Drug likeness: Lipinski's rules, ligand efficiency and lipophilic ligand efficiency. **Section – B** Computational Drug design: Structure based Drug Design, Molecular docking (rigid-body and flexible), virtual screening of libraries. Ligand based drug design: concept of pharmacophore, methods of pharmacophore generation and its applications in virtual screening. Bioisosteres, lead identification, optimization, and application of MD simulations in drug discovery and binding free energy calculations. **Section – C** Introduction to QSAR: Molecular descriptors used in QSAR studies: electronic; topological and quantum chemical. QSAR models: Free Wilson and Hansch equation. Statistical methods for QSAR modeling: regression, principal component, and partial least squares analysis. Validation of QSAR models: Cross validation, r^2, bootstrapping etc. **Suggested Readings:**	

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
				➢ Thomas G. (2003) Fundamentals of Medicinal Chemistry; John Wiley. ➢ Alvarez J. and Shoichet B. (Ed.) (2004). *Virtual Screening in Drug Discovery*. Taylor and Francis. ➢ Kukol, A. (Ed.) (2015). *Molecular Modeling of Proteins* (2nd Ed.). Springer Nature. Young, D.C. (2009). *Computational Drug Design*. John Wiley. ➢ S. Dastmalchi et al. (2018) Quantitative Structure–Activity Relationship A Practical Approach. CRC press.	
	BIN 502: Mining and Warehousing of Biological Data	After successful completion of the course the candidates should be able to: • Understand the knowledge discovery from the databases. • Categorizing the biological data based on various parameters. • Learn to use data mining tools.	**Mining and Warehousing of Biological Data Section A** **Fundamentals of Data Mining** – concept, definitions, why data mining, kind of data for data mining, knowledge discovery in databases (KDD), data mining functionalities, data mining primitives, classification of data mining systems, data mining techniques, major issues in data mining. **Data Preprocessing** – Needs for preprocessing the data, data cleaning, data integration and transformation, data reduction, data discretization and concept hierarchy generation. **Data Warehousing** – need, definitions, characteristics, data marts, metadata, operational versus analytical databases, data		No Change

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			warehouse architecture, multi dimensional data model, schemas for multidimensional databases, introduction to DMQL, implementation of data warehouse, OLAP, OLTP, ROLAP, MOLAP, HOLAP. **SectionB** **Association Rules Mining** – market basket analysis, apriori algorithm, FP-growth method, Mining Multilevel Association Rules from Transaction Databases, Mining Multidimensional Association Rules **Classification and Prediction** – classification by decision tree induction, classification by back propagation, linear and non-linear regression, classifier accuracy. **Clustering** – types of data in clustering, categorization of clustering methods, Major Clustering Methods (K-means, Hierarchal clustering, DBSCAN). **Section C** **Mining Complex Types of Data -** Spatial databases, multimedia databases, time-series and sequence data, text mining, web mining, trends in data mining, Introduction to various data mining tools (SAS Enterprise Miner 5.1, Oracle Data Mining, SPSS Clementine 8.5). ***Suggested Books:*** ➢ Han, J., Kamber, M. & Pei, J. (2012). *Data mining concept and technique* (3rd Ed.). Elsevier.		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			➢ Chen, J.Y. &Lonardi, S. (Eds.) (2017). *Biological Data Mining* (1st Ed.). Chapman and Hall/CRC. ➢ Elayidom, M. S. (2014). *Data Mining and Warehousing.* Cengage Learning. ➢ Baxevanis, A.D. & Ouellette, B.F.F. (2004). *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* (3rd Ed.). John Wiley. ➢ Morey, D., Maybury, M. &Thuraisinghan, B. (Eds) (2002). *Knowledge Management, Classic and Contemporary Works*; The MIT Press. **Suggested e-Resources:** ➢ **Data Mining** https://nptel.ac.in/courses/106105174/ ➢ **Data Mining: Concepts and Techniques** https://hanj.cs.illinois.edu/bk3/bk3_slidesindex.htm		
	CS512: Cloud Computing	After successful completion of the course the candidates should be able to: • Understand virtualization of machines. • Learn to use various cloud platforms.	**Cloud Computing** **Section A** Introduction to Cloud Computing, Definition, Characteristics, Components, Administering & Monitoring cloud services, benefits and limitations, Deploy application over cloud, Cloud computing platforms: Infrastructure as service: Platform as Service: Google App Engine, Introduction to Cloud Technologies, Study of Hypervisors, Compare SOAP and REST, Web services, AJAX and mashups-Web services:		No change

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			SOAP and REST, SOAP versus REST, AJAX: asynchronous 'rich' interfaces, Mashups: user interface services. **Section B** Virtualization Technology: Virtual machine technology, virtualization applications in enterprises, Pitfalls of virtualization, Multitenant software: Multi-entity support, Multi-schema approach, Multitenance using cloud data stores, Data access control for enterprise applications. Data in the cloud: Relational databases, Cloud file systems: GFS and HDFS, Map-Reduce and extensions: Parallel computing. **Section C** Cloud security fundamentals, Vulnerability assessment tool for cloud, Privacy and Security in cloud, Cloud computing security architecture: Architectural Considerations-General Issues, Trusted Cloud computing, Secure Execution Environments and Communications, Micro-architectures; Identity Management and Access control Identity management, Access control, Autonomic Security Cloud computing security challenges: Virtualization security management virtual threats, VM Security Recommendations, VM-Specific Security techniques, Secure Execution Environments and Communications in cloud. Issues in cloud computing, Implementing real		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			time application over cloud platform. **Suggested Books:** ➢ Puttini, R., Erl, T. & Mahmood, Z. (2013) *Cloud Computing: Concepts, Technology & Architecture*. ➢ Rittinghouse, J.W. &Ransome, J.F. (2010).*Cloud Computing, Implementation, Management, and Security*. CRC Press. ➢ Hurwitz, J., Bloor, R., Kanfman, M. & Halper, F. (2009) *Cloud Computing for Dummies*.Wiley India Edition. ➢ Rafaels, R. (2015). *Cloud Computing from Beginning to End*. Createspace Independent Publishing. **Suggested e-Resources:** ➢ **Cloud Computing** https://nptel.ac.in/courses/106105167/1 ➢ **Cloud Computing Specialization** https://www.coursera.org/specializations/cloud-computing		
	BIO 503: Fundamentals ofBioentrepreneurship	After successful completion of the course, students should be able to: • Understand role of entrepreneurship in promoting	**Fundamentals of Bioentrepreneurship** **Section-A** • Concept of entrepreneurship; Classification and types of entrepreneurship, Myths about entrepreneurship; Role of entrepreneurship in wealth building and creating an impact; Society, Technology and Entrepreneurship.		No change

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
		innovation and wealth generation. • Develop skills for writing business models for new ideas and market segments. • Explain various financial, marketing, sales and legal issues associated with entrepreneurship.	• Creativity and Innovation; Types and forms of Innovation; Sources of innovative opportunity; Entrepreneurship as a career option. **Section-B** • Introduction to the Design Thinking Process; Problem identification; Idea Generation; Value Proposition; Lean Canvas. • Identifying Customer Segments; Idea Validation; Developing Business Model; Sizing the opportunity; Building MVP; Concept of Start-up, Importance of Incubation. **Section-C** • Financial and Non financial support: Revenue streams; Pricing and Costs; Sources of funds; Importance of project management. • Marketing and Sales: Positioning; Channels and Strategy; Sales Planning. • Team: Importance of teambuilding; Complementary skill sets. • Legal issues: Brief overview of- intellectual property rights, patents, trademarks, copy rights, trade secrets, licensing and GI. • Business Plan writing. • Policies and Initiatives to promote Entrepreneurship in India. **Suggested Books:** ➢ Jain, P.C. (2001). Hand Book for New Entrepreneurs. UK: Oxford University		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			Press. ➢ Hisrich R. D., Manimala M. J., Peters Michael P. & Shepherd D. A. Entrepreneurship (9th ed.). McGraw Hill Publication. ➢ Roy, R. (2011). Entrepreneurship (2nd ed.). UK: Oxford University Press. ➢ Drucker, P. (2015). Innovation and Entrepreneurship (1st ed.). Routledge Classics. ➢ Kotler, P & Keller, K.L. (2017).Marketing Management (15th ed.). Pearson Publications ➢ Desai, V. (2011) Dynamics of Entrepreneurial Development & Management (6t ed.). Mumbai: Himalaya Publishing House. ➢ Khanka, S.S. (2007) Entrepreneurial Development. New Delhi: S. Chand & Company Ltd. ➢ Mohanty, S K. (2005). Fundamentals of Entrepreneurship. EEE Prentice Hall India Learning Private Limited. ➢ Gupta C.B. & Srinivasan N.P. (2013). Entrepreneurship Development in India. Sultan Chand & Sons. ➢ Gupta A.K. (2016).Grassroots Innovations (Minds On the Margin Are Not Marginal Minds). Random House. ➢ Patzelt, H., &Bernner, T. (Eds.). (2008). Handbook of Bioentrepreneurship.		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			Berlin, Germany: Springer. ➢ Robert, D. H., & Peters, M. P. (2002). Entrepreneurship. New York, USA: McGraw-Hill Education ➢ Shane, S. (2004). Academic Entrepreneurship: University Spinoffs and Wealth Creation. Northampton, M.A.: Edward Elgar **Suggested e-Resources:** ➢ https://www.startupcommons.org/what-is-startup-ecosystem.html ➢ https://getproductmarketfit.com/how-to-select-test-to-get-market-validation-for-new-product-or-business-idea/ ➢ https://www.coursera.org/learn/wharton-launching-startup ➢ https://www.coursera.org/learn/wharton-entrepreneurship-opportunity ➢ **Bioentrepreneurship** www.birac.nic.in/webcontent/jk.pdf ➢ **Biotechnology and entrepreneurship** http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.463.4354&rep=rep1&type=pdf ➢ **Accounts and Bioentrepreneur** https://www.nature.com/bioent/2003/031101/full/bioent779.html ➢ **Bioentrepreneurship** ➢ www.birac.nic.in/webcontent/jk.pdf		
	CS530:	After successful	**Neural Networks**		No Change

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
	Neural Networks	completion of the course the candidates should be able to: • Understand the automated classification methods. • Learn the basic theory of artificial intelligence.	**Section A** Introduction to Neural Networks, Models of a Neuron, Network architectures, feedback, learning process - error correction, learning, Hebbian, Competitive, Boltzman, Supervised and unsupervised learning, the perceptron model, Multilayer perceptrons. **Section B** Recurrent Networks, the Hopfield Network, the Boltzmann machine, its Markov Chain model, self organizingsystems :Hebbian learning, Competitive learning. **Section C** Moduler Networks, associative Model, Stochastic Model, Temporal processing : Back propagation learning, real time recurrent networks. VLSI implementations of Neural Networks : Design considerations, Neurocomputing hardware. **Suggested Books:** ➢ Bishop, C.M. (1995). *Neural Networks For Pattern Recognition*. Oxford University Press. ➢ Fausett L.V. (2004). *Fundamentals of neural networks*. Pearson Education ➢ Gurney, K. (1997) *An introduction to neural networks* . CRC press. **Suggested e- Resources:**		

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			➢ **Introduction to Neural Networks** http://www.cs.bham.ac.uk/~jxb/NN/ ➢ **Neural Networks and Deep Learning** https://www.coursera.org/learn/neural-networks-deep-learning		
	BIN601R Chemoinformatics	On completion of this course, students should be able to: • Understand the computational methods implemented for the chemistry. • Learn about different databases and techniques of chemoinformatics.	**Chemoinformatics** The informatics has influenced the fate of chemical sciences since last quarter of the 20th century, with evolution of computational methods such as combinatorial libraries, virtual screening and molecular modeling has led the medicinal chemists to speed up the drug discovery. To store the data computational chemists uses different nomenclatures such as SMILES and variety of file formats like MOL, MOL2 and SDF. The entire chemical space has been maintained in various databases such as PUBCHEM, DRUGBANK, NCI and ZINC. Further, the details of chemical reactions and novelty of the chemical species are maintained at chemical abstract service (CAS). Searching full or fragments of chemical structures involves pharmacophore methods, that forms the ground for ligand based drug discovery programs. The methods involve 3D searching of chemical space; Predicting different physico-chemical properties, toxicity of compounds has been a challenging task since the inception of		No change

First Semester					
S.No.	**Course List**	**Learning Outcome**	**Existing Syllabus**	**Suggested Syllabus**	**Remarks**
			chemoinformatics. **Suggested Books:** ➢ Leach A.R. Gillet V.J. (2007), An Introduction to Chemoinformatics. Springer Netherlands. ➢ Goodman J.M. (1998), Chemical Applications of Molecular Modelling, RSC Publications. ➢ Varnek A. (Ed.) (2017) Tutorials in Chemoinformatics. John Wiley and Sons Ltd. ➢ Bunin B.A., Siesel B., Morales G. &Bajorath J. (2007), Chemoinformatics: theory, practice and products. Springer Netherlands **Suggested E-resources** ➢ **Chemoinformatics** https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6146447/ ➢ **Databases and tools of medicinal chemistry** ➢ https://core.ac.uk/download/pdf/82152489.pdf		
	BIN602R: Immunoinformatics	On completion of this course, students should be able to:	**Immunoinformatics** Immunology is a core biological science course that deals with the immunity, classification of		No change

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		• Develop an understanding of immunology. • Understand the computational methods implemented for the immunology. • Learn about different databases of immunological importance.	Immunity, antigens, Immunoglobulins and biochemical processes in antigen – antibody reactions. The antigen representation is a challenging task to understand the antigen – antibody reactions, which are followed by th major histocompatibility complexes and variety of receptors such as T and B cell receptors. The immunology has played a great role in human health improvement by development of vaccines and organ transplantation. However, hyper-activation of immune system may result in the autoimmune disorders such as psoriasis. The informatics is currently playing great role in immunological sciences such as by developing databases dbMHC, IMGT, IPD, SYFPEITHI, Bcipep etc.). Bioinformatics methods such as molecular modeling, Protein – Protein/Peptide interactions are routinely being used to understand the Preptide-MHC Binding. Further the machine learning techniques are also being used to predict the MHC Binders, T-Cell Epitopes, MHC-Class I and II Binding Affinity. **Suggested Books:** Punt J., Stranford S., Jones P. & Owens J.A. (2018), Kuby Immunology (8th Ed.); W.H. Freeman & Company. ➢ Roitt I.M. & Delves P.J. (2001) Roitt's Essential Immunology(10th Ed.) Blackwell Science Ltd.		

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			➢ Flower D.R. (Ed.) (2007) Immunoinformatics: Predicting Immunogenicity in-silico. Humana Press: Methods in Molecular Biology. **Suggested E-Resources:** ➢ **Immunoinformatics** http://www.imgt.org/about/immunoinformatics.php		
	BT 529R: Drug Discovery	On completion of this course, students should be able to: • Understand basics of R&D in drug discovery and should be able to apply knowledge gained in respective fields of pharmaceutical industry. • Understand the role of synthetic chemistry in the development of pharmaceutical agents; and the modification of chemical structures to develop new drug	Modern drug discovery involves the identification of a target or drug lead using different techniques including molecular modeling, combinatorial libraries and high-throughput screening (HTS). Rational drug design is based on the understanding of the three-dimensional structures and physicochemical properties of drugs and receptors. Knowledge of molecular mechanisms, molecular dynamics simulations and homology modeling is necessary for studying drug/receptor interactions. The different conformational sampling techniques, fitness functions used in molecular docking and computational receptor-based and ligand-based drug design approaches are mostly used to design compounds with improved biological activity in rational drug design. Quantitative drug design using QSAR models are used to correlate structural molecular properties (descriptors) with functions (i.e.		No change

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		molecules. • Have an advanced understanding of the chemical structure of a pharmaceutical agent and determine the chemical group/s responsible for a given biological effect. • Demonstrate a basic understanding of pharmacogenomics and bioinformatics as it relates to drug design and discovery. • Develop an understanding of drug targets as a recognition site for pharmaceutical agents; how the chemical structure of a substance influences interaction with a drug target; and the identification of new drug targets for future drug discovery.	physicochemical properties, biological activities, toxicity, etc.) of the compounds. Understanding the structure activity relationship between the 3D structure of a molecule and its biological activity may act as the basis for the prediction of compounds with improved biological activities. Different bio-analytical assays (LC/MS/MS, GC/MS and ELISA) could be developed further in support of *in vitro* and *in vivo* studies. Understanding the principles as well as an early characterization of drug toxicity, adsorption, distribution, metabolism and excretion (ADME) along with drug-drug interactions, plasma protein binding assays and metabolite profile studies helps in eliminating compounds with unacceptable pharmacokinetic characteristics, which is critical to successful drug discovery programs. **Suggested Books:** ➢ Krogsgaard-Larsen *et. al*. (2016). *Textbook of Drug Design and Discovery*. 5th Edition. CRC Press. ➢ Satyanarayanajois, S. D. (2011). *Drug Design and Discovery: Methods and Protocols*. Humana Press. ➢ Rahman, A. U., Caldwell, G. W., and Choudhary, M. I. (2007). *Frontiers in Drug Design and Discovery.* Bentham		

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			Science publishers Limited. ➢ Dastmalchi, S. *et. al.* (2016). *Methods and Algorithms for Molecular Docking-Based Drug Design and Discovery*. IGI Global. **Suggested e- Resources:** ➢ **Drug Discovery** https://bit.ly/2tCqdtE ➢ **Peptide therapeutics** https://www.sciencedirect.com/science/article/pii/S1359644614003997 ➢ **Bio-analytical techniques** https://www.pharmatutor.org/articles/bioanalytical-techniques-overview		
	BT 531R: Human Genetics and Diseases	After successful completion of the course students will be able to: • Understand hereditary and molecular genetics with a strong human disease perspective. • Describe genetic abnormalities underlying human disease and disorders • Develop interest in biomedical research,	Since the rediscovery of Mendel's work in 1900, investigations on the genetic nature of human traits have gained significant importance. Understanding the genetic basis behind human disease is one of the most important reasons to study human chromosome structure, human karyotype, banding techniques, chromosome identification and nomenclature (ISCN)**.** Classical genetics has considerable importance in constructing genetic hypothesis from pedigree data analysis in monogenetic traits, autosomal dominant, autosomal recessive, sex linked dominant, sex linked recessive and sex influenced traits. The impact of consanguinity in causing sex linked		No change

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		genetic counseling, medicine, and clinical genetics	anomalies (haemophilia, colour blindness and Duchenne Muscular Dystrophy) has been observed in human population. Current knowledge on genetic variations across populations is applied to study human health and diseases which include chromosomal disorders, structural and numerical chromosomal anomalies (Klinefelter syndrome, Down's syndrome, Turner syndrome, Achondroplasia), inborn errors of metabolism (Phenylketonuria (PKU), Alkaptonuria, Albinism, Galactosemia), haemoglobinopathies, Thalassemia syndromes, multifactorial disorders (diabetes, schizophrenia, huntington disease). Medical genetics involves ethical issues therefore serious discussion is required for prenatal/adult diagnosis of genetic disorders, medical ethics, risks and benefits, informed consent and right of choice. **Suggested Books: Suggested Books:** ➢ Strachan T. & Read. A. (2011). *Human Molecular Genetics*(4th ed.). Garland Science ➢ Pasternak J. Fitzgerald. (1999). *An introduction to Human Molecular Genetics-Mechanism of Inherited Diseases*. Science Press. ➢ Thompson and Thompson.(2007).*Genetics in Medicine (7th Ed.*).Saunders **Suggested e- Resources**		

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			➢ **Chromosome identification and nomenclature (ISCN)** http://www.cydas.org/Resources/ISCN_Discussion.html ➢ **Pedigree data analysis** https://learn.genetics.utah.edu/content/disorders/ ➢ **Genetic disorders** https://www.genome.gov/10001204/specific-genetic-disorders/ ➢ **Prenatal/ adult diagnosis of genetic disorders, medical ethics** https://www.michiganallianceforfamilies.org/all/#sectionD		
	BT 539R: Protein Engineering	On completion of this course, students should be able to: • Analyse structure and construction of proteins by computer-based methods • Describe structure and classification of proteins • Analyse and compare the amino acid sequence and structure of proteins, and relate this information to the	An introduction to protein engineering for developing proteins with desired functions. Various methods (rational design and directed evolution) of protein engineering are employed to manipulate the different features or characteristics (affinity, specificity and stability etc) of proteins. Engineering various physicochemical and biological properties (stability to changes in parameters as pH, temperature, amino acid sequence and aggregation propensities etc) of the proteins could be important in their use as protein drugs and/or catalysts in bioreactors. The insight into the fundamental understanding of the mechanisms and forces (Van der waals, electrostatic, hydrogen bonding, weakly polar interactions, and hydrophobic effects), by		No change

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		function of proteins • Explain how proteins can be used for different industrial and academic purposes such as structure determination, organic synthesis and drug design. • Plan and carry out activity measurements of isolated proteins and characterize their purity and stability.	which protein stabilizes, will help in the formulation of protein based pharmaceuticals. Protein engineering with site-specifically incorporation of unnatural or non-canonical amino acids has been used to improve protein function for medical and industrial applications. Different computational approaches (sequence and 3D structure analysis, data mining, Ramachandran map etc) to protein engineering would help to address the requirements in order to find amino acid sequences that will optimize a desired property (physicochemical property and/or biological function) of a protein. Determination of the physicochemical properties of proteins using various spectroscopic methods (Far-UV and Near-UV CD, Fluorescence, UV absorbance and Optical rotatory dispersion) would further support the drug development process. Yeast surface display (YSD)has become a valuable protein engineering tool for modifying the affinity, specificity, and stability of antibodies, as well as other proteins. YSD could be successfully used for protein epitope mapping, identification of protein-protein interactions, and uses of displayed proteins in industry and medicine. Developing vaccines and peptidomimetics will further allow the investigators to identify novel therapeutic leads for numerous unmet clinical needs. **Suggested Books:**		

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			➢ Walsh, G.(2014). *Proteins: Biochemistry and Biotechnology*, Second edition. Chichester, West Sussex: Wiley Blackwell. ➢ Creighton, T. E. (1997). *Protein Structure: a Practical Approach*, 2nd Edition. Oxford University press. ➢ Cleland, J. L., and Craik, C. S. (2006). *Protein Engineering, Principles and Practice*, Vol 7. Springer Netherlands. ➢ Mueller, K., and Arndt, K. (2006). *Protein Engineering Protocols*, 1st Edition. Humana Press. ➢ Robertson, D., and Noel, J. P. (2004). *Protein Engineering Methods in Enzymology*, Vol 388. Elsevier Academic Press. ➢ Kyte, J. (2006). *Structure in Protein Chemistry*, 2nd Edition. Garland publishers. ➢ Williamson, M. P. (2012). *How proteins work*. New York: Garland Science. **Suggested E- Resources:** ➢ **Protein Engineering**: https://nptel.ac.in/courses/102103017/pdf/lecture%2022.pdf ➢ **Conformational stability of proteins**: https://bit.ly/2ViS7GQ		

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			Protein Engineering with Non-Natural Amino Acids: https://library.umac.mo/ebooks/b2805488x.pdf		