10, Institutional Area, Vasant Kunj,
New Delhi 110070

MINUTES OF THE 50th MEETING OF ACADEMIC COUNCIL HELD ON 08th JANUARY 2022 AT 11:00 A.M.

The 50th meeting of Academic Council was held on 08th January 2022 at 11:00 hours on Microsoft Team Platform.

The following were present:

Members

Professor Prateek Sharma, Chairperson
Mr Manoj Chugh
Professor Shaleen Singhal
Professor Arun Kansal
Professor Anandita Singh
Professor Ramakrishnan Sitaraman
Professor Vinay Shankar Prasad Sinha
Professor Nandan Nawn
Dr Naqui Anwer
Dr Sukanya Das
Dr Anu Rani Sharma
Dr Montu Bose
Dr Chander Kumar Singh
Dr Seema Sangita, Controller of Examination
Mr Kamal Sharma, Secretary

Special Invitees

Dr Shashi Bhushan Tripathi
Dr Chaithanya Madhurantakam
Mr Manish Shrivastava

Professor T C Kandpal, Professor Vivek Suneja, Professor Arun Kharat, Mr Rajesh Ayapilla, Mr Rahul Mittal and Professor Manipadma Datta could not attend the meeting.

Before starting the proceedings, the Registrar while welcoming the members, informed that Prof. Eklabya Sharma resigned from the services of the TERI SAS on 21 November 2021 and Prof. Prateek Sharma has been appointed as the Acting Vice Chancellor by the Chancellor with effect from 23 November 2021. Prof Prateek Sharma joined TERI SAS in August 2007 and has held the positions of Head, (DNR), Associate Dean, (Faculty of Applied Sciences) and Dean (Academic).

Prof Prateek Sharma welcomed the Board members before requesting the Registrar to take up the agenda items.

Item No.1: **To confirm the minutes of the Forty ninth Meeting of the Academic Council held on 17th July 2021**. The Registrar informed that minutes of the Forty-Ninth Meeting of the Academic Council, held on 17th July 2021, were circulated to the members and few minor comments received from the internal members have been incorporated. Hence, the Council might confirm the minutes.

TS/AC/50.1.1 The Council resolved that the minutes of the 49th Academic Council Meeting held on 17th July 2021 be confirmed.

Item No. 2: To consider and approve Promotion Rule of Students and Grade Conversion. The Controller of Examination explained to the members that TERISAS has received several requests from students and alumni for a grade conversion formula over the last few years. Hence, there is a need for a policy on grade conversion. In order to finalize a policy, three faculty members undertook the task of researching and reviewing policies followed in other institutions (**detailed in Enclosure 1**) in the context of the comments received on this matter in the past AC meetings. A range of different options were narrowed down to four, and their merits and demerits were assessed (detailed in **Enclosure 2**) and presented for consideration in the internal AC meeting. Based on the discussions in the internal AC meeting, a presentation on the proposal for grade conversion was made. This proposal is based on following principles:

- CGPA and percentage systems of evaluation of students are fundamentally different in characteristics and there is no uniform and scientifically rigorous method of conversion. Hence, the final decision is based on precedence in other institutions and universities like ours.

- The policy of "Grade Conversion" may be delinked with "Continuation of Registration/eligibility of degree requirements" (reasons are elaborated in **Enclosure 2**)
- Set the notional conversion from CGPA to percentage with a formula of multiplication by a factor of 10.[1]
- CGPA of 6 and above may be notionally considered first division

An extensive discussion was carried out on the merits and demerits of this proposal

1. The presentation showed data on the minimum, maximum and average CGPA of each program for the last two years to demonstrate that only a selected few students would score a 90% or higher after conversion. It was pointed out that this may not be sufficient. The entire distribution may be studied for at least three years and may be compared with similar outcomes in other universities. In view of the time that it would take to undertake such a task, it was suggested that this approach be considered while drafting any future iterations of the policy.
2. There was a detailed discussion on specific details as well as merits and demerits of the proposal.
3. After reflecting on the circumstances, it was felt that the proposal would be an acceptable way forward in the best interest of the future of our students and alumni. Further, it was based on precedence set by other similar institutions. Majority of the AC agreed with this conclusion. Prof. Nandan Nawn expressed his disagreement regarding the second part of the conversion statement, that is, notional consideration of CGPA of 6 and above as first class.

Final conversion from CGPA to percentage policy text:

TERI-SAS adopts the following formula for notional conversion of CGPA to percentage terms for the purpose of internship/employment/scholarships/higher education, etc. for all its graduates since the inception of the university:

Percentage = 10*[CGPA]

A CGPA of 6 and above may be notionally considered to be first class.

[1] This is option 1 in Enclosure 2. The merits and demerits are outlined there.

TS/AC/50.2.1 The Academic Council resolved to approve the final conversion from CGPA to percentage and first class of CGPA 6 and above as presented by the Controller of Examinations.

Item No. 3: **To approve the number of seats in various programmes**. Prof Arun Kansal, Dean (Academic) informed that after internal discussion with the Head of Departments, it is proposed to reduce the number of seats to 20 from present 25 in respect of MSc (Geoinformatics) and MSc (Biotechnology) programmes due to the infrastructure constraint and lab space requirements. However, for MSc (Economics) it is proposed to increase the seats from present 40 to 60 due to the high number of applications received. For other programmes, there is no change in the number of seats. The Academic Council is requested to consider and approve the number of seats with respect to the above mentioned three programmes.

TS/AC/49.3.1 The Academic Council resolved to approve the revised number of seats in respect of the above mentioned three programmes.

Item No. 4: **To consider and approve courses to be offered in Second Semester of M.Sc. Biotechnology Programme.** Dr Shashi Bhushan Tripathi presented and requested the Academic Council to approve the courses to be offered in second semester of M.Sc (Biotechnology) programme, as placed at **Enclosure 3**. He also further stated that each of the proposed course

- is in accordance with the programme structure approved by the AC
- has been reviewed by atleast two subject experts
- has been discussed and recommended by the Board of Studies

TS/AC/50.4.1 The Academic Council resolved to approve the courses to be offered in the second semester of MSc (Biotechnology) programme as placed at **Enclosure 3**.

Item No. 5: **To consider and approve revised course outline of "Climate Change and Law" offered to M.Sc. Climate Science and Policy.** Dr Manish Shrivastava informed that this course was earlier offered by the Centre for Postgraduate Legal Studies with course code MPL134 which has been discontinued from AY 2021-22. Few suggestions and recommendations of BoS were incorporated in the course structure as placed at **Enclosure 4** and requested the Academic Council for its approval.

TS/AC/50.5.1 The Academic Council resolved to approve the revised course outline of "Climate Change and Law" as placed at **Enclosure 4**.

Item No. 6: **To obtain concurrence on approval of resolution by circulation.** The Registrar informed that in the 49th Academic Council meeting, it was decided to align the course credits to 15 hour per credit for all programmes as per the UGC rules. According to this decision, all the programmes has gone through their respective Board of Studies and carried out the required changes in each course(s) and the summary of the changes were circulated to the Academic Council members on 25 August 2021 for approval. After the Council's approval through circulation, it was implemented with effect from 31 August 2021.

The members noted the matter.

There being no other items for discussion, the meeting was adjourned with a vote of thanks to the Chair at 1440 hours.

Sd/
Kamal Sharma
Registrar (Acting)

Enclosures:-
Enclosure 1 Review of other institutions' grade conversion policies
Enclosure 2 Summary of the background review of different options
Enclosure 3 Courses to be offered in Second Semester of M.Sc. Biotechnology Programme
Enclosure 4 Revised course outline of "Climate Change and Law"

Distribution:-
Electronic Copy:
1. Vice Chancellor, TERI School of Advanced Studies
2. All members of Academic Council
3. Website

Printed Copy: Registrar Office

Enclosure 1

REVIEW OF OTHER INSTITUTIONS' GRADE CONVERSION POLICIES

1. Different institutes have different grade conversion formulae. Policies in IIT Delhi, Delhi University, JNU, Mumbai University, IIT Bhubaneswar, IIT Dhanbad, IIT Hyderabad, IIITM Gwalior, AMU, and Amity University were reviewed.
    a. Among these universities, IIT Delhi, Amity University, IIT Bhubaneswar, IIT Hyderabad, IIITM Gwalior multiply by a factor of 10. Most universities seem to use this straightforward conversion rule.
    b. IIT Dhanbad uses this formula: *Percentage = (CGPA-0.5) *10*.
    c. Mumbai University: *Percentage = 7.1*CGPA + 11*.
    d. Delhi University (undergraduate): *Percentage = 9.5*CGPA*
    e. JNU*: Percentage = 5 + 10*CGPA*
2. None of the institutions explain the logic behind the choice of conversion formula.
3. The review did not reveal any perfect way to map the CGPA to percentage as these two methods of assessment of a student are fundamentally different in characteristics. In fact, two institutions - IIT Bhubaneswar and Amity University - clearly state that there is no rigorous formula to convert CGPA to percentage terms. But, they accept method of multiplication of CGPA by 10 if a student requires a conversion of CGPA to percentage.

References:

1. IIT Delhi
    a. They use a direct conversion of factor of 10
    b. https://home.iitd.ac.in/uploads/IITD-Courses-of-Study-2021-22_(08-09-2021).pdf – pg 17 (4.2.2) indicates that different programs have different eligibility criteria. Regardless all use the same conversion rate.

अतुल व्यास
Atul Vyas
उप कुलसचिव
Deputy Registrar

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No. IITD/A&E(PGS)/A-2/2017/ 69798
Dated: 24th July 2017

TO WHOM IT MAY CONCERN

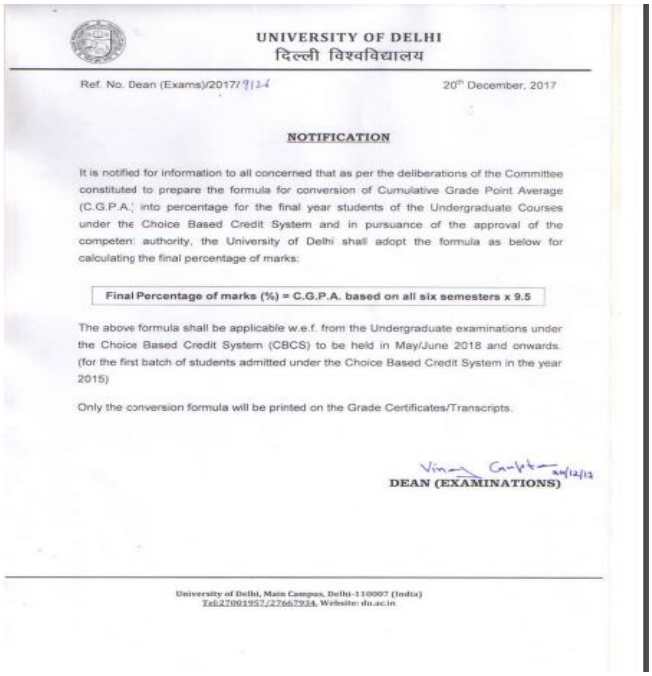
The CGPA of all IIT Delhi graduates notionally be converted to percentage by multiplying the CGPA by a factor of 10. This is applicable for all graduates since 18.10.1982.

For the purpose of employment or requirement of any external body that IIT Delhi graduate wishes to join, a CGPA of 6.0 or above be taken as First Class.

(ATUL VYAS)

Note: This certificate will not be issued to the individual candidates/ agencies for now onwards. It may be downloaded from the website.

2. Delhi University
    a. http://exam.du.ac.in/pdf/11012018/11012018_CGPA.pdf



UNIVERSITY OF DELHI
दिल्ली विश्वविद्यालय

Ref. No. Dean (Exams)/2017/9124 — 20th December, 2017

NOTIFICATION

It is notified for information to all concerned that as per the deliberations of the Committee constituted to prepare the formula for conversion of Cumulative Grade Point Average (C.G.P.A.) into percentage for the final year students of the Undergraduate Courses under the Choice Based Credit System and in pursuance of the approval of the competen: authority, the University of Delhi shall adopt the formula as below for calculating the final percentage of marks:

Final Percentage of marks (%) = C.G.P.A. based on all six semesters x 9.5

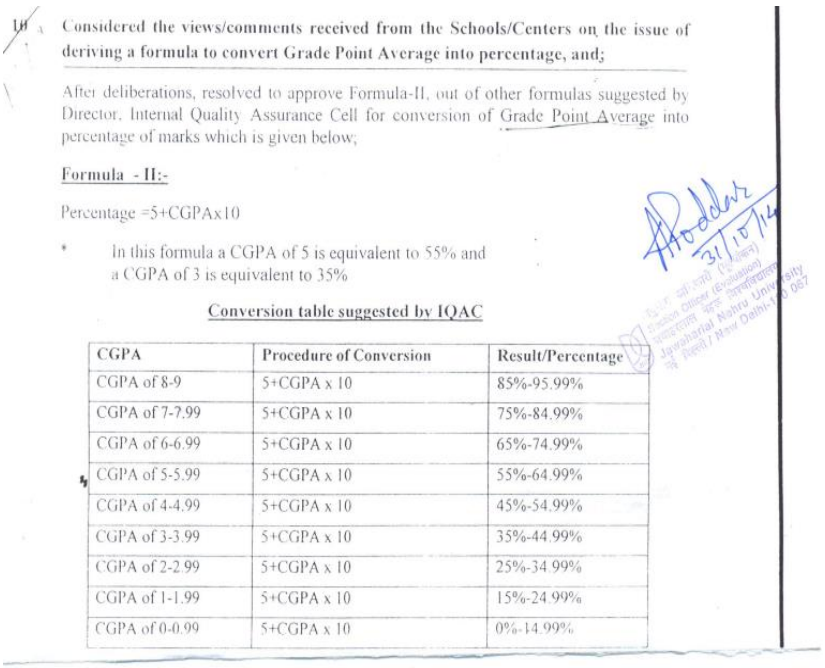
The above formula shall be applicable w.e.f. from the Undergraduate examinations under the Choice Based Credit System (CBCS) to be held in May/June 2018 and onwards. (for the first batch of students admitted under the Choice Based Credit System in the year 2015)

Only the conversion formula will be printed on the Grade Certificates/Transcripts.

Vinay Gupta 20/12/17
DEAN (EXAMINATIONS)

University of Delhi, Main Campus, Delhi-110007 (India)
Tel:27001957/27667934, Website: du.ac.in

3. JNU
    a. https://www.jnu.ac.in/sites/default/files/Conversion%20certificate.pdf



Considered the views/comments received from the Schools/Centers on the issue of deriving a formula to convert Grade Point Average into percentage, and;

After deliberations, resolved to approve Formula-II, out of other formulas suggested by Director, Internal Quality Assurance Cell for conversion of Grade Point Average into percentage of marks which is given below;

Formula - II:-

Percentage =5+CGPAx10

* In this formula a CGPA of 5 is equivalent to 55% and a CGPA of 3 is equivalent to 35%

Conversion table suggested by IQAC

CGPA	Procedure of Conversion	Result/Percentage
CGPA of 8-9	5+CGPA x 10	85%-95.99%
CGPA of 7-7.99	5+CGPA x 10	75%-84.99%
CGPA of 6-6.99	5+CGPA x 10	65%-74.99%
CGPA of 5-5.99	5+CGPA x 10	55%-64.99%
CGPA of 4-4.99	5+CGPA x 10	45%-54.99%
CGPA of 3-3.99	5+CGPA x 10	35%-44.99%
CGPA of 2-2.99	5+CGPA x 10	25%-34.99%
CGPA of 1-1.99	5+CGPA x 10	15%-24.99%
CGPA of 0-0.99	5+CGPA x 10	0%-14.99%

4. Amity
    a. https://www.amity.edu/placement/Popup.asp?Eid=441 (Amity uses a factor of 10 for placement purposes)
    b. https://img0cf.b8cdn.com/images/course/70/1869170_1552134911.pdf (towards the end of the transcript, they state that conversion from CGPA to percentage has no rigor or rationale)
5. Mumbai University
    a. https://mu.ac.in/wp-content/uploads/2014/03/conversion-Circular_2017.pdf
    b. I am not quite sure of the rationale of this formula.
6. IIT Bhubaneshwar
    a. https://www.iitbbs.ac.in/notice/noticeb_1516190404.pdf
    b. They state that there is no formula for conversion but students can use multiplication by 10 if they need to.
7. IIT Dhanbad
    a. https://www.iitism.ac.in/assets/uploads/news_events/admin/CGPA-to-Percentage.pdf
8. IIT Hyderabad
    a. https://www.iith.ac.in/academics/assets/files/forms/CGPA-to-percentage-conversion.pdf

   b. Section 3.5.4 indicates that D is passing grade which carries 4 points.
9. IIITM Gwalior
   a. https://www.iiitm.ac.in/images/2019/June_2019/Academics_2019/Conversion-Certificate-CGPA-1.pdf
   b. https://www.iiitm.ac.in/images/2019/June_2019/Academics_2019/Prospecus2019_final.pdf (D is the passing grade with 4 points, and the minimum CGPA required is 5, see pg 25 to 27

Enclosure 2

SUMMARY OF THE BACKGROUND REVIEW OF DIFFERENT OPTIONS

Discussions in the previous AC meetings presented the dilemma of whether to benchmark the "traditional pass percentage" of 40% with a CGPA of 4 which is the passing grade of each course or with a CGPA of 6 which is the minimum requirement of award of degree. This dilemma is difficult to resolve. The "additional illustration" in the footnote gives one example of challenges faced.[2] Four different options were studied with the objective of trying to find a resolution, keeping in mind the feedback received in the previous AC meetings.

The following is a summary of 4 strategies reviewed and discussed in the internal meeting:

OPTION 1: Delink Conversion Formula and Promotion Criteria. Regardless of promotion criteria, use a rule of multiplication by 10 for conversion.

MERITS

- This approach bypasses the dilemma described above.
- Many universities and engineering institutions follow this approach. In the absence of availability of methodology for a scientifically rigorous conversion between CGPA and percentage, the next best approach may be to follow the norms in the sector.
- The choice of multiplication by 10 (as opposed to say 9.5 or 9) is justified by our moderate pattern of final CGPAs where a selected few students make it to a CGPA>9. Thus, only a selected few would score 90% or more after conversion.
- Ease of implementation, as there would be one uniform rule across cohorts.

[2] **Additional illustration:** An example to explain the challenges of benchmarking with the minimum CGPA requirement for award of degree. The minimum CGPA for award of degree was 5.5 prior to 2018 and 6 thereafter.

Suppose CGPA 6 is benchmarked as 40% (traditional pass percentage) after 2018. Then using the same approach CGPA 5.5 ought to be benchmarked as 40% prior to 2018. Now, if we consider two students, both with CGPA of 6, one graduated in 2019 and another in 2017, then these two students would have different percentage marks. The former would have a percentage score of exactly 40% while the later would have a percentage score higher than 40%

Therefore, use of benchmarks based on "minimum CGPA for award of degree" in any method for percentage conversion or for estimating class divisions would not be consistent across cohorts.

- In the circumstance that no perfect solution that could address all the feedback of previous AC meetings could be found, this solution is the second best approach
- Divisions can be pegged at 1st class or 1st division for 60% and above, as is the traditional norm in Indian Universities.

DEMERITS

- This is not based on a strict scientific rationale but is based only on what several institutions in India appear to follow.
- The question of 10 and why not 9.5 or 9 also does not have a strict scientific rationale
- Choice of divisions also does not have a strict scientific rationale.

OPTION 2: Allow award of degree to students CGPA of 4 and multiplication by 10 is the conversion formula with 4 = 40% as the passing benchmark.

This option was presented in last AC meeting, and was reviewed in light of the comments received

MERITS

- Dilemma of benchmarking the "traditional pass percentage" to 4 or 6 is resolved by creating an equivalence of grade point for passing a course and CGPA of award of degree. In this option, both would be set at 4.
- The formula of multiplication by 10 for percentage marks and also setting up the divisions as per the norms of traditional Indian university system of first class/division for 60% of higher is in alignment with this option

DEMERITS

- As pointed out in the last AC meeting, reduction of the minimum CGPA required for award of degree from 6 to 4 may be perceived as reduction in the academic standards of the university.
- This will not provide a conversion for current and past cohort of students for whom the minimum CGPA required for award of degree cannot be changed retrospectively.

OPTION 3: Y = 14.5*X - 47", where Y is the equivalent percentage and **X is the CGPA/SGPA and CGPA of 6.0 is made equivalent to 40% marks and CGPA of 10.0 is made equivalent to 98% marks**[3]

CGPA	Equivalent %	Division	CGPA range	Conversion Formula
6.00	40.00	Pass without division	6.0 ≤ CGPA <6.69 40 ≤ Percentage <50	Y = 14.5*X - 47 X = CGPA/SGPA Y = Equivalent %
6.50	47.25			
6.69	50.01			
6.70	50.15	2nd division	6.7 ≤ CGPA < 7.4 51 ≤ Percentage < 60	
7.00	54.50			
7.40	60.30			
7.50	61.75	1st division	7.5 ≤ CGPA < 8.4 61 ≤ Percentage < 74	
8.20	71.90			
8.40	74.80			
8.50	76.25	1st division with Distinction	10.0 ≤ CGPA ≥ 8.5 75 ≤ Percentage ≥ 98	
9.00	83.50			
9.50	90.75			
10.00	98.00			

MERITS

- Elegant Formula, a good attempt at trying to achieve scientific rigour
- Benchmarks 40% to CGPA 6
- Has a clear indication of the divisions

DEMERITS

- Different conversion formula with similar methods would have to be created for past students who graduate with a CGPA of 5.5.
- There would be intertemporal inconsistencies. It would be difficult to justify why a particular CGPA has different percentage conversions prior to 2018 and post 2018.

[3] Credit for this formula goes to Dr. Naqui Anwer

- In case the CGPA rule is changed in future, the conversion rule also will have to change. There would be a need to reach out to experts for creating such formula, leading to administrative costs.
- Pass grade of each individual course is D which carries 4 grade points is not addressed in this formula.

OPTION 4: Eliminate D grade. So, passing grades would be A+ to C. C has a score of 5. Also, CGPA of 5 would be set minimum requirement for award of degree. Following this, 50%, based on a formula of multiplication by 10 could be set as pass percentage.

MERITS

- Creates parity between the pass grade at a course level and the minimum CGPA required for graduation. Then, the dilemma of benchmarking the pass percentage to individual course vs final aggregate CGPA is resolved.

DEMERITS

- Eliminating D grade would not be in alignment with the norms in other universities.
- This will not provide a conversion formula for current and past cohorts of students for whom the minimum CGPA required for award of degree cannot be changed retrospectively.
- The alignment of divisions may not match the traditional Indian university norms.

CONCLUSION OF INTERNAL MEETING:

The meeting also acknowledged that options 2, 3 and 4 would have a range of inconsistencies across different cohorts that follow different rules of minimum CGPA which would be difficult to explain. **Hence, option 1 may be the way forward.** The demerits of option 1 were recognized and reflected upon in detail. It was also acknowledged that finding a strict scientific rationale that could also resolve internal consistencies as well as be administered with reasonable ease was, perhaps, not feasible. Hence adopting an option that many other universities and institutions followed may be an agreeable way forward.

Enclosure 3

A. Approval of Semester 2 courses of M.Sc. Biotechnology Programme

Following eight courses of Semester 2 of M.Sc. Biotechnology Programme were presented to the Academic Council.

1. Conservation genetics and genomics

Observation: No changes were suggested in this course and BoS approved the detailed structure

2. Microbial pathogenesis

Observation: No changes were suggested in this course and BoS approved the detailed structure

3. Molecular Cell Biology: From Genes to Communities

Observation: There were no changes suggested and BoS approved the detailed structure

4. Genome organization and molecular markers

Observation: The course coordinator informed that one of the reviewers suggested changing the title of this course to "Genome Structure and Diversity: Concepts and Methodologies" to make it more meaningful and appropriate. The BoS accepted the observation of the reviewer. Further, it was requested that the total credit of the course be increased from 2 to 3 considering a large number of new concepts as suggested by the reviewers. The BoS accepted this proposal based on comments and opinions received by the course coordinator. It was decided that the overall credit of the Programme is also increased from 75 to 76 to accommodate this change in course credit.

5. Biotechnology Laboratory- Part 2

Observation: Laboratory was designed for common as well stream specific practicals, the BoS asked to segregate the experiments into Part A (which will be common for students of both the streams) and Part B1 as only for the Microbial Biotechnology stream while Part B2 will be only for Plant Biotechnology Stream.

6. Introduction to Nanobiotechnology

Observation: The BoS members suggested, as this is an introductory course on Nanobiotechnology for Biotechnology students, a greater emphasis needs to be on the application of Nanobiotechnology in areas such as agriculture, health and medicine. The topics such as synthesis and characterization of Nanomaterials may be dealt with at a basic level.

7. Molecular Plant Physiology and Metabolism

Observation: It was suggested that the topic of respiration might be removed, as it is already part of the course in Biochemistry. A greater emphasis needs to be given to the topic of the Physiology of plant development and flowering.

8. Molecular microbiology and immunology

Observation: No changes were suggested in this course and BoS approved the detailed structure.

B. Approval of the revised programme structure of the M.Sc. Biotechnology Programme

The name of the course, Genome organization and molecular markers, has been changed to Genome Structure and Diversity: Concepts and Methodologies. Further, the total credit of the course has been increased from 2 to 3. Consequently, the total credit of the Programme needs to be increased from 75 to 76. Accordingly, the revised programme structure outline of the M.Sc. Biotechnology Programme is provided below.

Programme outline for M.Sc. Biotechnology*

Year	Courses	Credits	Duration
First Year			
1st Semester	7 core courses of 2-7 credits each, and 2 core audit courses	21	15 weeks
2nd Semester	7 core courses of 2-7 credits and 1 course of 2 credits in the area of specialisation**	23	15 weeks
Second Year			
3rd Semester	4 core courses of 2-7 credits and 1 course of 2 credits in the area of specialisation**	16	15 weeks
4th Semester	Major project	16	15 weeks

*In addition to above, a minimum 4 credits equivalent of elective courses (audit only) listed below need to be completed during the Programme which may be taken in any semester when

offered by the concerned Department and provided it doesn't conflict with any other course taken by the student. There is no upper limit for the number and credit equivalent for Elective courses.
**Specialisation specific practical component equivalent to 2 credits will carried out under Biotechnology Laboratory- Part 2 (2nd Semester) and Biotechnology Laboratory- Part 3 (3rd Semester) each.

Semester 1				
Course No.	**Course title**	**Type**	**Number of Credits**	**No. of L-T-P**
BBP 105	Biotechnology Laboratory - Part 1	Core	7	7-0-196
NRE 101	Communication Skills and Technical Writing	Audit	2*	16-12-0
BBP 155	Principles of Genetic Engineering and Recombinant DNA Technology	Core	3	30-15-0
NRE 113	Applied Mathematics	Audit and bridge course	0*	31-11-0
BBP 158	Conceptual Foundations of Molecular Biology	Core	2	30-0-0
BBP 154	Principles of Biochemistry and Biophysics	Core	2	30-0-0
BBP 111	Bioanalytical Techniques	Core	3	39-6-0
BBP 123	Plant and Animal Biotechnology	Core	2	30-0-0
BBP 174	Bioinformatics and Computational Biology	Core	2	22-8-0

Semester 2				
Course No.	**Course title**	**Type**	**Number of Credits**	**No. of L-T-P**
TBA	Conservation Genetics and Genomics	Core	2	30-0-0
TBA	Biotechnology Laboratory -	Core*	7	0-0-210

Semester 2				
Course No.	**Course title**	**Type**	**Number of Credits**	**No. of L-T-P**
	Part 2			
TBA	Introduction to Nanobiotechnology	Core	2	22-8-0
BBP 130	Molecular Microbiology and Immunology	Core	2	30-0-0
BBP 112	Statistics for The Life Sciences	Core	3	28-14-0
BBP 114	Molecular Cell Biology - From Genes to Communities	Core	2	30-0-0
TBA	Genome Structure and Diversity: Concepts and Methodologies	Core	3	23-22-0
TBA	Molecular Plant Physiology and Metabolism	Specialization (Plant Biotechnology)	2	30-0-0
TBA	Microbial Pathogenesis	Specialization (Microbial Biotechnology)	2	15-15-0

*Specialisation specific practical component equivalent to 2 credits will carried out under Biotechnology Laboratory- Part 2

Semester 3				
Course No.	**Course title**	**Type**	**Number of Credits**	**No. of L-T-P**
TBA	Biotechnology Laboratory - Part 3	Core*	7	
BBP 141	Bioethics, IPR and Regulations in Biotechnology	Core	3	
TBA	Gene Expression Analysis and Transcriptomics	Core	2	
TBA	Proteomics and Protein	Core	2	

Semester 3				
Course No.	**Course title**	**Type**	**Number of Credits**	**No. of L-T-P**
	Engineering			
TBA	Functional Genomics in Plants	Specialization (Plant Biotechnology)	2	
TBA	Bioprocess Engineering and Environmental Biotechnology	Specialization (Microbial Biotechnology)	2	

*Specialisation specific practical component equivalent to 2 credits will carried out under Biotechnology Laboratory- Part 3

Elective courses* (Audit only)				
Course No.	**Course title**	**Type**	**Number of Credits**	**No. of L-T-P**
NRE 131	Environmental Chemistry and Microbiology	Elective	3	35-7-0
NRE 165	Introduction to Sustainable Development	Elective	1	14-0-0
TBA	Nanomaterials: Introduction and Applications	Elective	2	
NRE 123	Biodiversity Assessment and Conservation	Elective	3	17-15-20
NRE 168	Food Security and Agriculture	Elective	3	23-16-6
NRE 112	Multivariate Data Analysis	Elective	3	28-14-0
NRE 151	Wildlife Conservation and Management	Elective	3	35-7-0

*Elective courses may be taken in any semester when offered by the concerned Department and provided it doesn't conflict with any other course taken by the student. There is no upper limit for the number and credit equivalent for Elective courses.

Courses to be offered in Second Semester of M.Sc. Biotechnology Programme

Course title: Conservation Genetics and Genomics			
Course code: BBP ---	**No. of credits:** 2	**L-T-P:** 30-0-0	**Learning hours:** 30
Pre-requisite course code and title (if any): Science graduate			
Department: Department of Natural and Applied Sciences			
Course coordinator:		**Course instructor:**	
Contact details:			
Course type: Core		**Course offered in:** Semester 2	

Course description:

The broad objective of this course is to provide the students a foundation on the concepts, tools and techniques of classical genetics, population genetics and genomics as applied in conservation of biodiversity. The students will be acquainted with various factors that affect the genetic composition of natural populations. Considering the importance of next generation sequencing in generating data for characterization of populations, a module on genome sequencing and its applications in genetic diversity assessment has been included. Further, topics on microbial genetic diversity such as 16S RNA sequencing and metagenomics have also been included.

Course objectives:

1. To introduce the students to concepts of classical and modern genetics
2. To introduce the students to concepts of population and conservation genetics
3. To familiarize the students to next generation sequencing platforms
4. Applications of next generation sequence data for characterisation of genetic resources

Course contents

Module	**Topic**	**L**	**T**	**P**
1	**Principles of Evolution and Population genetics**	6	0	0
	• Principles of evolution and Natural selection • Population attributes and structure • Gene and genotype frequency: Hardy-Weinberg Equilibrium; changes in gene frequency through natural selection, migration and random genetic drift; Population bottlenecks			

	• Adaptive radiation; Speciation; Allopatric and Sympatric; Convergent evolution; • In-breeding depression & mating systems			
2	**Introduction to conservation genetics**	6	0	0
	• Introduction to conservation genetics, • Concepts of gene pool (primary, secondary, tertiary) • Natural variation: Phenotypic and genetic diversity including allelic richness; Analysis of genetic diversity • *In situ* and *ex situ* conservation, core collections			
3	**Principles of Genetics and mapping**	12	0	0
	• Genetics and inheritance: Laws and exceptions • Recombination and linkage mapping • Quantitative genetics and mapping, polygenic inheritance, heritability; Linkage disequilibrium			
4	**Genomics platforms for population and conservation genetics**	6	0	0
	• Introduction to next generation sequencing platforms, Pyrosequencing, Illumina, Single molecule real time (SMRT) sequencing • 16S RNA based analysis of microbial diversity and taxonomy, metagenomics • Nuclear and Organellar DNA for conservation and diversity			
	Total	**30**	**0**	**0**

Evaluation criteria:

1. Test 1- (Module 1) 30%
2. Test 2- (Module 2) 30%
3. Test 3- (Modules 3 and 4) 40%

Learning outcomes:

1. Students will be able to use the principles of evolution and population genetics (Test 1)
2. Basic understanding of principles of germplasm conservation (Test 1-2)
3. Understanding of principles of genetics (Test 2-3)
4. Basic understanding of next generation sequencing platforms and their application in

genetic diversity analysis (Test 3)

Pedagogical Approach:

1. Online/classroom lectures and discussions
2. Case studies and examples from original research articles

Skill Set:

1. Next generation sequencing platforms
2. Germplasm characterisation using principles of population genetics
3. 16S RNA sequencing and metagenomics analysis

Employability:

1. Forestry and wildlife research institutions
2. Academic organisations
3. Companies providing genotyping and sequencing services

Materials:

Suggested Readings

1. A Primer of Ecological Genetics. Conner, J. K. and D. L. Hartl. Sinauer Associates. 2009
2. Conservation and the Genetics of Populations. 2nd edition. Allendorf, Luikart and Aitken. 2013.
3. Adaptive radiations: From field to genomic studies. Scott A. Hodges, Nathan J. Derieg. Proceedings of the National Academy of Sciences Jun 2009, 106 (Supplement 1) 9947-9954; DOI: 10.1073/pnas.0901594106
4. Methods in Molecular Biology, vol. 376: Linkage Disequilibrium and Association Mapping: Analysis and Applications Edited by: A. R. Collins © Humana Press Inc., Totowa, NJ

Additional information (if any):

Student responsibilities:

1. Class attendance.
2. Study of reading materials as specified by course instructor
3. Self-study

Course reviewers:

1. Prof. Sandip Das, Department of Botany, University of Delhi, New Delhi
2. Dr. R. Yasodha, Scientist G, Institute of Forest Genetics and Tree Breeding, Coimbatore

3. Dr. Ram Kumar Sharma, Scientist G, Institute of Himalayan Bioresource and Technology, Palampur, Himachal Pradesh

Course title: Microbial pathogenesis			
Course code:	**No. of credits:** 2	**L-T-P:** 15-15-0	**Learning hours:** 30
Pre-requisite course code and title (if any): None			
Department:			
Course coordinator(s):	**Course instructor(s):** Internal faculty member(s) and external experts.		
Contact details:			
Course type: Core	**Course offered in:** Semester 2		

Course description: Microbial diseases impose significant social and economic burdens on human society. However, the insights gained from both medicine and basic biology thus far have led to a better understanding of disease mechanisms. This new knowledge has greatly helped in the prevention, management and cure of several diseases. This course aims to impart an understanding of some of the current paradigms in microbial pathogenesis.
The study material for this course will include textbooks, case studies and articles from field journals.
This is a highly participatory course with a significant component of self-study of assigned material from the literature and student presentations of case studies. Problem-based learning will be a critical component of the evaluation process. Evolutionary and ecological perspectives will be emphasized to provide a truly integrative framework to understand host-pathogen interactions and their consequences.

Course objectives:

1. To present key aspects of the biology of different pathogens and their interactions with the host.
2. To enable synthesis of information in order to study communicable diseases within an evolutionary-ecological framework.

Course contents

S.No	Topic	L	T	P
Module 1	**Introduction**			
1	Symbiosis, parasitism and evolution	2		
2	Pathogens and Koch's postulates. Contribution of '-omic' sciences to our understanding of pathogens.	1		
3	Modes of disease transmission, epidemics and the spread of anti-microbial resistance	3		
Module	**Mechanisms and Molecules**			

2				
1	Host-pathogen interactions at the molecular level, host resistance and susceptibility genes and the determinants of outcomes.	4		
2	The microbiome in health and disease	3		
3	Diagnostics, vaccines and therapeutic agents	2		
Module 3	**Case studies in microbial pathogenesis**			
1	SARS-CoV-2 and the WHO vaccine programme		3	
2	Anthrax – an acute zoonotic disease		3	
3	Tuberculosis – a chronic and worldwide problem		3	
4	Helicobacter pylori – commensal, pathogen and carcinogen		3	
5	ESKAPE pathogens: *Pseudomonas aeruginosa* – a wide-ranging opportunist		3	
	Total	**15**	**15**	0

Evaluation criteria:
Test 1 – 30% weightage
Test 2 – 30% weightage
Test 3 – 40% weightage

Learning outcomes:
1. Knowledge of basic concepts in the field (Tests 1-3).
2. Ability to critically analyze and synthesize primary data to develop coherent models or frame testable hypotheses (Tests 1-3).
3. Detailed understanding of pathogens and their strategies for colonization, immune evasion and dispersal (Tests 2-3).

Pedagogical Approach:
Online/offline lectures and self-study assignments. Detailed discussion and student presentation of articles from peer-reviewed journals in class for module 3.

Skill Set:
1. Critical analysis of concepts, hypotheses and experimental design.
2. Formulation of experimental strategies for molecular genetic studies of model host-pathogen systems.
3. Comparative analysis of preventive and therapeutic strategies.

Employability:
1. Academic and industrial research on microbial pathogens.
2. Intellectual property firms.
3. Life science teaching at school and undergraduate levels.
4. Pathology laboratories.

5. Management and/or supervision of laboratory-based research in academic/industrial/medical settings.

Materials:

Required texts

1. B.A. Wilson *et al.* Bacterial Pathogenesis: A Molecular Approach. ASM Press, ed. 4, 2019.
2. J.C. Herron, S. Freeman. Evolutionary Analysis. Pearson Education, India. ed. 5, 2013.
3. B. Tungland. Human Microbiota in Health and Disease: From Pathogenesis to Therapy. Elsevier Science, 2018.
4. Viral Pathogenesis, From Basics to Systems Biology. Academic Press, ed. 3, 2016.
5. N. Bergman. *Bacillus anthracis* and Anthrax. Wiley-Blackwell, 2010.
6. P. Sutton & H. Mitchell (eds.). *Helicobacter pylori* in the 21st Century (Advances in Molecular and Cellular Biology Series). CABI, 2010.
7. S.E. Hasnain *et al*. *Mycobacterium tuberculosis*: Molecular Infection Biology, Pathogenesis, Diagnostics and New Interventions. Springer Singapore, 2019.
8. B.H.A. Rehm (ed.). *Pseudomonas*: Model Organism, Pathogen, Cell Factory. Wiley-VCH, 2008.
9. R. Rappuoli & F. Bagnoli (eds). Vaccine Design: Innovative Approaches and Novel Strategies. Horizon Scientific Press, 2011.
10. S. Pan & J. Tang (eds.). Clinical Molecular Diagnostics. Springer, 2021.
11. L. Pirofski & A. Casadevall. *mBio* 11(4), e01175-20 (2020). doi: 10.1128/mBio.01175-20
12. E.Janik *et al. Medicina,* 56(11), 591 (2020). doi: 10.3390/medicina56110591
13. S. Suerbaum & P. Michetti. *New England Journal of Medicine* 347(15), 1175-86 (2002). doi: 10.1056/NEJMra020542
14. L.I. Rankine-Wilson *et al*. *Microbiology (Reading)*167(4):001041 (2021). doi: 10.1099/mic.0.001041
15. I. Jurado-Martín *et al. Int J Mol Sci.* 22(6), 3128 (2021). doi: 10.3390/ijms22063128.
16. Y. Taoufik *et al. Front Immunol*. 2021 12, 692598 (2021). doi: 10.3389/fimmu.2021.692598.
17. M.J. Culyba & D. van Tyne. *PLoS Pathog* 17(9), e1009872 (2021). doi: 10.1371/journal.ppat.1009872

Case studies

Suggested readings

Journals

Other readings

Additional information (if any):

Student responsibilities: 1. Class attendance (online/offline). 2. Study/self-study/presentation of course materials as specified by the instructor. 3. Ensuring functionality of essential IT hardware & software at their preferred location(s).

Course reviewers:

1. Prof. Vijaya Satchidanandam, Department of Microbiology and Cell Biology, Indian Institute of Science, Bengaluru (superannuated) and Adjunct Professor, St. John's Medical College, Sarjapur Road, Bengaluru – 560034
2. Dr. S. Ramachandran, Chief Scientist, Professor of the AcSIR in the Faculty of Biological Sciences, Room 130, CSIR-Institute of Genomics and Integrative Biology, Mathura Road, Near Sukhdev Vihar Bus Depot
   New Delhi 110 025

Course title: Molecular Cell Biology: From Genes to Communities			
Course code:	**No. of credits:** 2	**L-T-P:** 30-0-0	**Learning hours:** 30
Pre-requisite course code and title (if any): None			
Department:			
Course coordinator(s):	**Course instructor(s):**		
Contact details:			
Course type: Core	**Course offered in:** Semester 2		

Course description: This course will highlight the physiological versatility that underlies the ability of organisms to adapt to varying needs of their respective developmental stages, environmental stimuli and ecological niches. Advanced and contemporary themes in molecular and cell biology will be highlighted as indicated. The course is divided into three modules to facilitate the analysis of living systems at progressively more complex levels. This course will help students gain new knowledge in, and develop their own perspectives on the rapidly expanding field of modern biology.

Course objectives:

1. To present an integrative view of cellular processes at progressively complex levels.
2. To enable synthesis of isolated information in order to analyze biological phenomena in a contextually relevant manner.
3. To delineate the overarching role of evolutionary considerations at multiple levels of complexity.

Course contents

S.No	Topic	L	T	P
Module 1	**The genetic material**			
1	The evolution of complexity.	3	0	0
2	The dynamic nature of the genome Recombination, gene conversion, extrachromosomal elements, horizontal gene transfer, transposition, transduction, phase variation, DNA rearrangements and the vertebrate adaptive immune system	3	0	0
3	Epigenetics Epigenetic mechanisms of gene regulation, non-coding RNAs in gene regulation and cellular defence.	3	0	0
Module 2	**Cellular processes – from molecules to cells**			
1	Model organisms – overview of *E. coli*, *S. cervisiae* (yeast), *C.*	2	0	0

	elegans, D. melanogaster, and *A. thaliana*			
2	Spatio-temporal gene regulation Molecular processes underlying the eukaryotic cell cycle,cell signalling and responses, regulatory networks and cross-talk between cellular pathways, protein secretion and localization.	5	0	0
3	A systems view of regulatory processes in biology. Types of regulatory mechanisms, bistabilty, intrinsic and extrinsic noise, synthetic biology.	3	0	0
Module 3	**Organisms to ecosystems**			
1	Microbial interactions Gene transfer, barriers to gene transfer, quorum sensing, host-microbe interactions, symbiosis and pathogenesis.	5	0	0
2	Microbial communities and the microbiota – an evolutionary-ecological synthesis. The self versus non-self recognition conundrum.	6	0	0
	Total	**30**	0	0

Evaluation criteria:
Test 1 – 30% weightage
Test 2 – 30% weightage
Test 3 – 40% weightage

Learning outcomes:
1. Detailed knowledge of specific aspects of model living systems in consonance with topics in the outline (Tests 1-3).
2. Ability to critically analyze and synthesize primary data to develop coherent models (Tests 1-3).
3. Understanding implicit evolutionary arguments underlying the analysis of organisms from the genetic to community levels (Tests 1-3).

Pedagogical Approach:
Online/offline lectures emphasizing the detailed discussion of research/review articles from scientific journals in class.

Skill Set:
1. Design of molecular biology/genetic engineering experiments.
2. Critical analysis of molecular biology/genetic engineering experimental design and results.
3. Formulation of experimental strategies for molecular genetic studies of simple model organisms.
4. Analysis and design of complex regulatory networks.

Employability:

1. Academic and industrial research involving molecular biology approaches.
2. Intellectual property firms.
3. Life science teaching at school and undergraduate levels.
4. Management and/or supervision of laboratory research in academic/industrial settings.

Materials:

Required texts

1. J. D. Watson., *et al.* Molecular Biology of the Gene. Pearson, Cold Spring Harbor, ed. 7, 2014.
2. S. Brenner. *Phil. Trans. R. Soc. B*, 365, 207–212 (2010).
3. M. W. Gray *et al. Science*, 330, 920-921 (2010).
4. A. Rokas. *Nature*, 443,401-402 (2006).
5. T.D.P. Brunet, W.F. Doolittle. *Biol Philos* 33, 2 (2018). doi: 10.1007/s10539-018-9614-6.
6. I. R. Henderson, S. E. Jacobsen. *Nature* 447, 418-424 (2007).
7. V.L. Chandler. *Cell*, 128 (4), 641-645 (2007).
8. B. Alberts, *et al.* Molecular Biology of the Cell. Garland Science, New York, ed. 5, 2008.
9. D. G. Gibson *et al. Science*, 329, 52-56 (2010).
10. R.J. Hall, *et al*. *Front Microbiol* 11:1569. doi: 10.3389/fmicb.2020.01569 (2020).
11. J. -H. Hehemann et al. *Nature*, 464, 908-912 (2010).
12. N. C. Reading, V. Sperandio. *FEMS Microbiol Lett*, 254, 1-11 (2006).
13. O.P. Duddy, B.L. Bassler. *PLOS Pathogens* 17(1): e1009074. doi: 10.1371/journal.ppat.1009074 (2021).
14. E. K. Costello et al. *Science*, 336, 1255-1262 (2012)

Case studies

Suggested readings

1. J. E. Krebs *et al.* Lewin's GENES XII. Jones and Bartlett Publishers, Inc., Burlington, ed. 12, 2017

Journals

Other readings

Additional information (if any):

Student responsibilities:

1. Class attendance (online/offline).
2. Study/self-study of course materials as specified by the instructor.
3. Ensuring functionality of essential IT hardware & software at their preferred location(s).

Course reviewers:

1. Prof. Vijaya Satchidanandam, Department of Microbiology and Cell Biology, Indian Institute of Science, Bengaluru (superannuated) and Adjunct Professor, St. John's Medical College, Sarjapur Road, Bengaluru – 560034
2. Dr. S. Ramachandran, Chief Scientist, Professor of the AcSIR in the Faculty of Biological Sciences, Room 130, CSIR-Institute of Genomics and Integrative Biology, Mathura Road, Near Sukhdev Vihar Bus Depot
   New Delhi 110 025

Course title: Genome Structure and Diversity: Concepts and Methodologies			
Course code: BT XXX	**No. of credits:** 3	**L-T-P:** 23-22-0	**Learning hours: 45**
Pre-requisite course code and title (if any): None			
Faculty:	**Department:** Department of Natural and Applied Sciences		
Course coordinator(s):	**Course instructor(s):**		
Contact details:			
Course type: Core	**Course offered in:** Semester 2		

Course description:

The extraordinary diversity among living organisms is reflective of structural and functional diversity of genomes. The tree of life is strident evidence of evolutionary processes underlying biological variation. Genome elucidation studies are crucial for gaining insights into the molecular basis of morphological diversity and trait variation. This advanced course provides a conceptual framework on genome architecture and experimental methods for analysis of its components and sequences. In the first module, students will gain insights on features of diverse genomes, hierarchies of genome organisation, variability in genome complexity and content and dynamic nature of genomes at varying levels of resolution. In the second module, a critical appraisal of traditional marker techniques and modern, sophisticated genotyping platforms vis-à-vis relative efficiencies in polymorphism detection will be discussed. Introduction to next generation, genomics based, genotyping platforms will sensitize the students to frontier areas of research directed towards sustainable agriculture, generation of climate resilient crops and healthcare products. Third module is designed to inform the students, by way of interesting case studies, application of markers in sectors of plant, animal and microbial biotechnology. Through this course, students will gain a holistic perspective on "genotype-phenotype association" by integration of core principles related to diverse disciplines as molecular genetics, genomics and evolution.

Course objectives:

1. Building perspectives on structure and variability in genomes and its constituents
2. Illustrating the relationship between genotypic and phenotypic variation
3. Introducing versatile methodologies, concepts and applications of molecular marker techniques

Course contents

Module1	**Genome Structure and Organization (Prokaryotes and Eukaryotes)**	**L**	**T**	**P**

1	**Genome diversity** (Viral, Bacterial, Archaeal, Eukaryotic, Auxiliary DNA structures viz. Plasmids and Organellar genome); **Hierarchies of Genome Organization** (Genomic sequences, chromatin, nucleosomes, packaging, 3D genomes and chromosome territories); **Dynamic genomes and variability in Genome Content (**Genome sizes and complexity, C-Value paradox, Unique and repeat DNA sequences; Tandem and Interspersed repeats, Mobile Elements, Micro- and Mini-satellites, hyper-variable VNTRs, Whole Genome Multiplications and Fractionation, DNA rearrangements, SNPs and Structural variation (Microscopic and sub-microscopic, Copy Number Variation, Presence Absence Variation, Inversions, Mobile Element Insertion and Deletions, Homologous Exchange Variation); **Variability in gene categories and structure** (Protein coding genes, non-protein coding genes, Intron-less and interrupted genes (Structure of exons, introns, variability in number, size, GC-content); Intron types; poly-cistronic genes, overlapping genes (+/+ and +/- strand); cis-regulatory regions (Promoter, bi-directional promoters, Enhancers, Insulators, Terminators), case studies to illustrate structural variations as basis for phenotypic diversity, notion of genome maps	6	6	
Module 2	**Genome analysis by Genetic markers**			
2	**Molecular Markers and DNA fingerprinting techniques** Definition of trait, classification genetic markers, molecular basis of dominant and co-dominant markers; Restriction Fragment Length Polymorphism, MAAP (Multiple Arbitrary Amplicon Profiling) and other PCR based markers (DNA Amplification Fingerprinting, Arbitrarily Primed PCR, Randomly Amplified Polymorphic DNA, SSRs, STMS, SCARs, Inter-SSRs, Amplified Fragment Length Polymorphism, Selectively Amplified Microsatellite Polymorphic Loci, Inter retrotransposon amplified polymorphism, retrotransposon-microsatellite amplified polymorphism, Intron spanning markers, SNP based marker assays (CAPs, dCAPs, dHPLC, molecular beacons, 5'nuclease assay/TaqMan assays, FEN based Invader reactions), Eco-TILLING (Targeting induced local lesions in the genome); **Modern Genotyping platforms** Array based genotyping (Affymetrix axiom, Affymetrix genechip, Illumina Infinium Bead Chip; NGS based genotyping methods (GBS, DArT-seq, RAD-seq, ddRAD, REST-seq); de-novo sequencing and/or WGS (PacBio. HiC. 10X Chromium, Oxford nanopore, HiSeq4000/NovaSeq6000, IonTorrent)	12	12	
Module 3	**Applications and key concepts related to marker technology: Case Studies**			

3	**Diversity analysis in plants** Geographical diversity, center of origin, domestication, gene pools, pan-genomes and super-pangenomes; methods (numerical taxonomy and phenetics), conservation of plant genetic resources; **Diversity analysis in microbes** (Microbiomes, structures and functions, 16S to metagenomics); **Molecular Breeding** (MAS, Genomics Assisted Breeding); plant variety protection; DNA barcoding; hybrid purity tests; diagnostics (transgenics, forensics); establishing clonal fidelity; BAC fingerprinting; LD/ Haplotype mapping, GWAS in context to natural populations (animals and plants), **human diseases** (mapping human diseases, risk prediction, discovery of drug targets and improving healthcare), genomic selection in plants and animals	5	4	
	Total	**23**	**22**	

Evaluation criteria:

1. Test 1: 30%
2. Test 2: 30%
3. Test 3: 40%

Learning outcomes:

1. An understanding on structure and variability in genomes and its constituents **(Test 1-3)**
2. Ability to rationalize deployment of genotyping techniques for relevant applications **(Test 1-3)**
3. Understanding genetic and molecular basis of phenotypic variation **(Test 1-3)**

Pedagogical Approach:

Lectures and tutorials in online or offline mode with a major emphasis on the detailed discussion of original research articles

Skill Set:

1. Generating and interpreting DNA fingerprints and profiles for forensics
2. Developing natural and synthetic microbiomes as biofertilizers, biopesticides, healthcare products
3. Testing Hybrid purity
4. Diagnosing varieties, cultivars, accessions and land races
5. Ascertaining clonal fidelity for tissue culture raised regenerants
6. Applying MAS (Marker Assisted Selection) strategies in breeding programmes
7. Introducing transgenes for development of new plant varieties
8. DNA bar-coding technology
9. Evaluating gene-flow in transgenic field trials
10. Formulating appropriate conservation strategies
11. Innovating genome interrogation methods for unarticulated research problems

Employability:

1. Forensic Science laboratories, molecular diagnostic testing laboratories

2. Genotyping and sequencing companies
3. Agri-biotechnology and seed companies
4. Tissue culture and horticulture companies
5. Law firms and knowledge processing organizations (IP management consultancy)
6. Regulatory bodies and funding agencies

Materials:

Suggested readings (Representative)

1. Krieg, N.R., Ludwig, W., Whitman, W.B., Hedlund, B.P., Paster, B.J., Staley, J.T., Ward, N. and Brown, D. (eds., 2010). Bergey's Manual of Systematic Bacteriology, 2nd ed., vol. 4, Springer-Verlag, New York, NY
2. Dale, J.W., Schantz, M.V. and Plant, N. (2011). From Genes to Genomes: Concepts and Applications of DNA Technology. Third edition. John Wiley & Sons, UK.
3. Brown, T. A. (2017). Genomes 4. CRC Press, Taylor & Francis Group, USA.
4. Krebs J.E, Goldstein E.S., Kilpatrick S. T. (2018) Lewin's GENES XII. Jones and Bartlett Learning. USA
5. Meksem K., Kahl G. (2005) The Handbook of Plant Genome Mapping: Genetic and Physical Mapping, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim
6. Varshney R., Pandey M., Chitikineni A (2018) Plant Genetics and Molecular Biology. Advances in Biochemical Engineering / Biotechnology series number 164. Springer Nature, Switzerland
7. Varshney R., Roorkiwal M., Sorells M (2017) Genomic Selection for Crop improvement: New Molecular Breeding strategies for crop improvement. Springer Nature, Switzerland
8. Research and review articles on relevant topics
9. Scherer, S., & Visscher, P. (2016). Genome-Wide Association Studies: From Polymorphism to Personalized Medicine (K. Appasani, Ed.). Cambridge: Cambridge University Press. doi:10.1017/CBO9781107337459

Student responsibilities:

1. Class attendance
2. Study of course materials as specified by the instructor
3. Self-study

Course reviewers:

1. Prof. Surekha Katiyar-Agarwal
Department of Plant Molecular Biology
University of Delhi, South Campus, New Delhi- 110021, India

2. Dr. Neeti Sanan Misra
Group Leader: Plant RNAi,
International Centre for Genetic Engineering and Biotechnology
Aruna Asaf Ali Marg
New Delhi-110 067, India

Course title: Biotechnology laboratory – Part 2			
Course code: BBP ---	**No. of credits:** 7	**L-T-P:** 0-0-210	**Learning hours:** 210
Pre-requisite course code and title (if any): None			
Department: Department of Natural and Applied Sciences			
Course coordinator:	**Course instructor:**		
Contact details:			
Course type: Core/Specialization	**Course offered in:** Semester 2		

Course description:

The objective of this laboratory course is to introduce students to experiments related to biotechnology. The course is designed to teach students the utility of set of experimental methods in biotechnology in a problem-oriented manner. The list of experiments given in each module is representative and includes experiments. Part A will be common for both the streams. Part B1 is only for Microbial Biotechnology stream whereas Part B2 is only for Plant Biotechnology stream. The instructor may choose experiments for student's laboratory training as per requirements.

Course objectives:

1. To introduce the students to standard techniques of molecular biology.
2. To impart intensive hands-on-training using molecular tools in a research project mode.
3. To train the students in designing experiments with appropriate controls.

Course contents

Module	Topic	L	T	P
Suggested practical				
	PART A: Common to both streams			154
	I- Genotyping methods and analysis of data- 1. Genotyping of natural populations with ISSR markers 2. Genotyping of natural populations with SSR markers 3. Analysis of molecular data using MS Excel- marker attributes 4. Analysis of molecular data using GeneAlex- Cluster analysis 5. Analysis of molecular data using Corehunter or PowerCore- Core collections 6. Genotyping of mapping populations with SSR markers 7. Genotyping of mapping populations with ISSR markers 8. Construction of linkage maps with marker data 9. Identification of QTLs using mapping populations 10. GWAS using SNP data 11. Marker-trait associations in natural populations 12. ISSR fingerprinting for clonal uniformity testing 13. Processing of fastq files by FastQC/FastP (quality, trimming etc.)			

	II- Molecular biology techniques- 1. Isolation of total cellular RNA from diverse plant tissue samples, qualitative and quantitative assessment 2. Synthesis of first strand cDNA using M-MuLV reverse transcriptase 3. RT-PCR for analysing spatio-temporal expression pattern of candidate genes 4. Designing artificial miRNAs 5. Analysis of relative expression levels using qRT PCR 6. qRT PCR for protein coding/ miRNA genes 7. Quantitation of relative expression levels (delta delta CT method) by Livak and Schmittgen and RQ method by Knight et al. (2009) 8. Overlapping PCR for joining promoter elements to CDS for construction of artificial gene **III- Analytical Techniques** 1. Macromolecular analysis by Dynamic Light Scattering (DLS) a. To detect aggregate formations of a protein using DLS b. To detect the size of a protein molecule and to analyse the protein-ligand complex through DLS analysis. 2. ELISA Assays: a. To determine the Ag conc. by sandwich ELISA b. To determine the Ab capture by Ab capture ELISA method. c. To determine the Ag conc. by Ag capture ELISA method. d. To perform Dot-ELISA to detect an antigen.			
	PART B1: Microbial Biotechnology			56
	I- Immuno-Techniques and Assays- 1. Immunodiffusion and Immuno-precipitation assays: a. To study immunodiffusion techniques by single radial Immunodiffusion. b. To perform Ouchterlony double diffusion. 2. To determine antibody concentration by using quantitative precipitin assay. 3. Antibody Titrations: a. To detect titre value of antibodies, present in serum due to the infection of Salmonella genus causing enteric or Typhoid Fever by quantitative tube agglutination test. b. To detect the titre value of antibodies, present in test serum by using quantitative tube agglutination test			

	II- Techniques in microbiology- 1. Isolation and identification of a probiotic strain from a fermented drink 2. 16S rRNA amplification and sequencing of a mixed culture. 3. Isolation and assay of phages from the environment. 4. Examination of bacterial motility using soft agar medium 5. Sporulation of bacteria 6. Evaluating environmental bacterial isolates for antibiotic production			
	PART B2: Plant Biotechnology			
	1. Selfing and emasculation, setting up of controlled crosses 2. Making rooted cuttings in Sweet Basil (effect of different rooting mixtures) 3. Effect of salt stress/ABA on stomatal conductance/proline concentration 4. Seed viability testing and grow out test **5.** Pollen viability testing **6.** Histochemical staining for transgene expression 7. Plant genetic transformation 8. Generation of Arabidopsis transgenics by floral dip method 9. Micrografting 10. Root system architecture analysis			56

Evaluation criteria:

1. Attendance: 5%
2. Preparation of lab record(s) throughout the semester: 25%
3. End semester evaluation: 70% (Following components would be included)
   a) Spotting: 15 %
   b) Viva-voce: 15 %
   c) Experiment(s) assigned on the day of the exam: 40%

Learning outcomes:

1. Ability to conduct experiments with adequate safety precautions.
2. Capacity to compare and evaluate various approaches in solving a given experimental problem.
3. Ability to design and interpret molecular biology experiments.
4. Proficiency in defining a research problem, drawing logical inferences from results and documenting outcomes in systematic manner.

Pedagogical Approach: Laboratory experiments, demonstration, writing and experiments result analysis.

Skill Set:

1. Able to work in biotechnology lab and perform experiments
2. Able to analyses experimental data and critical thinking.

Employability:

1. Academic and industrial research
2. Industries based on biotechnology, pharmacy, and agriculture.

Materials-

1. Study material and laboratory protocol will be provided by course instructor.
2. "Biochemistry Laboratory: Modern Theory and Techniques" Rodney Boyer, second Edition, Pearson Education, 2012.
3. "Analytical Techniques in Biochemistry and Molecular Biology" Rajan Katoch, Springer, 2011.
4. "Molecular cloning: A laboratory manual" Sambrook, Joseph. & Russell, David W. & Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y : Cold Spring Harbor Laboratory, 2001.
5. "DNA and protein sequence analysis. A Practical approach" Bishop M.J., Rawlings C.J. (Eds.)1997.

Website

1. https://nptel.ac.in/

Journals

1. Peer reviewed relevant scientific journals.

Advanced Reading Material

Will be provided by instructor, if require.

Additional information (if any)

List of experiments given in each module are representative, instructor may choose any of them for student's laboratory training as per requirements.

Student responsibilities

1. Class attendance.
2. Study of course materials as specified by the instructor.
3. Regular submission of given class assignments.

Reviewers

1. Prof. Bijoy Neog, Department of Life Sciences, Dibrugarh University, Dibrugarh, Assam
2. Dr. Rupesh Chaturvedi, Ramalingaswami Fellow, National Agri-food Biotechnology Institute, Mohali, Punjab

<table>
<tr><td colspan="5">Course title: Introduction to Nanobiotechnology</td></tr>
<tr><td colspan="2">Course code:</td><td>No. of credits: 2</td><td>L-T-P: 22-08-0</td><td>Learning hours: 30</td></tr>
<tr><td colspan="5">Pre-requisite course code and title (if any):</td></tr>
<tr><td colspan="2">Faculty:</td><td colspan="3">Department: Department of Natural and Applied Sciences</td></tr>
<tr><td colspan="2">Course coordinator:</td><td colspan="3">Course instructor</td></tr>
<tr><td colspan="5">Contact details:</td></tr>
<tr><td colspan="2">Course type: Core</td><td colspan="3">Course offered in: Semester 2</td></tr>
<tr><td colspan="5">Course description:
Nanotechnology is an interdisciplinary field and attracts students from various disciplines. This course provides basic overview of nanomaterials and their applications. This course begins with a review of various types of nanomaterials and an introduction to general terminologies. Subsequently the course covers synthesis methodologies, physical and chemical characterization of nanomaterials. Finally, case studies illustrating application of nanomaterials in diverse fields will be discussed.</td></tr>
<tr><td colspan="5">Course objectives:
1. To understand the nature and properties of nanomaterials.
2. To provide scientific understanding of application of nanomaterials and nanotechnology in agriculture, health and environmental conservation</td></tr>
<tr><td colspan="5">Course contents</td></tr>
<tr><td>S.No</td><td>Topic</td><td>L</td><td>T</td><td>P</td></tr>
<tr><td>1.</td><td>Introduction to nanomaterials;
• Various types of nanomaterials, Three-dimensional, two-dimensional, one-dimensional and zero-dimensional nanomaterials.
• Carbon nanotubes, Graphene, Carbon dots, metal nanoparticles, metal oxide-based nanomaterials, semiconductor nanomaterials, quantum dots, hybrid nanoparticles,
• Bio-nanomaterials, polymer nanoparticles, lipid nanoparticles etc.
• Synthesis methodologies, Top down and bottom up approaches for nanomaterial synthesis.</td><td>4</td><td>2</td><td>0</td></tr>
</table>

2.	**Properties of nanomaterials** • Structural properties, chemical properties, surface functionalization, physical properties. • Characterization of nanomaterials by various analytical methods, optical characterization and spectroscopy such as FT-IR, UV-Vis, DLS, Zetapotential, structural characterization by X-Ray Diffraction, XPS and advanced microscopy (TEM, SEM, AFM) etc.	**4**	**4**	**0**
3.	**Nanobiotechnology in healthcare;** • Role of nanobiotechnology in the area of infectious & non-infectious diseases • Nanopharmaceuticals • Diagnosis, sensors and biosensors • Delivery vehicles, biomedical applications of nanomaterials. Multimodal nanoparticles, targeted drug delivery, theranostics	**8**		
4.	**Nanobiotechnology for Agriculture:** Nanotechnology based tools to enhance agricultural productivity • Nanobased Agri and Food Products, food preservation and toxicity • Nanopesticides and Nanofertilizers • Nano-biostimulants and soil enhancers • Nano-enabled technologies and abiotic stress management • Nanobiotechnology for Crop improvement • Precision Delivery Systems • Diagnostics and sensing • Nanotechnology for environment: contamination detection and remediation	**6**	**2**	**0**
		22	**8**	
Evaluation criteria: 1. Test 1 and 2: 20% weightage to each 2. Test 3 (end semester): 50% weightage 3. Assignment: 10% weightage				

Learning outcomes:

1. Familiarity with working principles, tools and techniques in the field of nanomaterials.
2. Understanding of the strengths, limitations and potential uses of nanomaterials.

Materials:

Suggested readings:(*1–7*)

1. A. L. Rogach, *Semiconductor nanocrystal quantum dots synthesis, assembly, spectroscopy and applications* (Springer, Wien; London, 2008).
2. E. Gazit, *Plenty of room for biology at the bottom: an introduction to bionanotechnology* (Imperial College Press ; Distributed by World Scientific Pub. in the USA, London : Hackensack, NJ, 2007).
3. G. E. J. Poinern, *A laboratory course in nanoscience and nanotechnology* (CRC Press, Taylor & Francis Group, Boca Raton, 2015).
4. C. A. Mirkin, C. M. Niemeyer, Eds., *More concepts and applications* (Wiley-VCH, Weinheim, 2007), *Nanobiotechnology*.
5. A. K. Mishra, Ed., *Application of nanotechnology in water research* (Wiley, Scrivener Publishing, Hoboken, New Jersey, 2014).
6. K. R. Nill, *Glossary of biotechnology and nanobiotechnology terms* (Taylor & Francis, Boca Raton, 4th ed., 2006).
7. J. Kim, Ed., *Advances in nanotechnology and the environment* (Pan Stanford, Singapore, 2012).
8. P. N. Prasad. Nanophotonics (Wiley, New York, 2003).

Websites

Journals

Other readings

Additional information (if any):

None

Student responsibilities:

1. Study of course materials as specified by the instructor
2. Timely submission of given class assignment

Course reviewed by:

1. Dr. Amit K Dinda, MD, Ph.D
   Professor
   Department of Pathology
   All India Institute of Medical Sciences, New Delhi

President, Indian Society of Renal & Transplant Pathology (ISRTP)
Secretary, Indian Society of Nanomedicine (ISNM)
Fellow, Electron Microscopy Society of India (EMSI)
dindaaiims@gmail.com

2. Dr Indrajit Roy, Ph.D
Associate Professor
Department of Chemistry,
University of Delhi,
Delhi-110007.
indrajitroy11@gmail.com

Course title: Molecular Plant Physiology and Metabolism			
Course code: BBP ---	**No. of credits:** 2	**L-T-P:** 30-0-0	**Learning hours:** 30
Pre-requisite course code and title (if any): Science graduate			
Department: Department of Natural and Applied Sciences			
Course coordinator:		**Course instructor:**	
Contact details:			
Course type: Specialization		**Course offered in:** Semester 2	

Course description:

This course is designed for the students who have opted for Plant Biotechnology as the stream of specialization in the M.Sc. Biotechnology Programme. The course aims to provide a comprehensive knowledge of molecular plant physiology. The main topics include photomorphogenesis, hormones, water relations, photosynthesis and stress physiology.

Course objectives:

1. To provide a foundational understanding of key plant physiological processes
2. To provide knowledge of molecular mechanisms of plant metabolism and development
3. Knowledge of plant stress physiology and tolerance mechanisms
4. Familiarity with secondary plant metabolites

Course contents

Module	Topic	L	T	P
	Photomorphogenesis: Role of light in growth and development, Circadian rhythms, Phytochrome, Cryptochrome and Phototropins	4	0	0
	Phytohormones: Biosynthesis, mode and mechanism of action, biological functions, perception and signaling (Auxins, Cytokinins, Gibberellins, Ethylene, Abscisic Acid, Brassinosteroids), Polyamine, Salicylic acid and Jasmonic acid	6	0	0
	Physiology of plant development and flowering: Embryogenesis, apical, basal & radial patterning; Developmental control of root and shoot apical meristem; Molecular mechanism of floral induction and development	7	0	0
	Plant nutrients: Uptake and utilization, Solute transport, Plant water relationships, hydroponics	2	0	0

	Physiology of biotic and abiotic stress, Molecular plant-pathogen interactions	3	0	0
	Photosynthesis (C_3, C_4 and CAM), photorespiration	3	0	0
	Metabolism of secondary metabolites in plants, Phenolics, Terpenoids and Alkaloids, biochemical and physiological significance	3	0	0
	Biological N_2 fixation, Plant growth promoting Rhizobacteria, Amino acid metabolism, Urea cycle	2	0	0
	Total	**30**	**0**	**0**

Evaluation criteria:

1. Test 1- (Module 1-3) 30%
2. Test 2- (Module 3-5) 30%
3. Test 3- (Modules 5-9) 40%

Learning outcomes:

1. An understanding of photomorphogenesis and plant hormones (Test 1)
2. An understanding of floral induction and water relations and stress tolerance mechanisms (Test 1-2)
3. An understanding of electron transport, secondary metabolites, and nitrogen metabolism (Test 2-3)
4. An ability of making hypotheses related to plant metabolism and development (Test 1-3)

Pedagogical Approach:

1. Online/classroom lectures and discussions
2. Case studies and examples from original research articles

Skill Set:

1. Developing and screening mutants with novel traits
2. Ability to develop strategies for genetic improvement of crops having climate resilience

Employability:

1. Academic and research organisations
2. Tissue culture facilities and horticulture companies
3. Agri-biotechnology and seed companies
4. Pharmaceutical and drug research companies

Materials:

Suggested Readings

1. Plant Physiology, Sixth Edition" by Lincoln Taiz and Eduardo Zeiger
2. Biochemistry & Molecular Biology of Plants by Bob Buchanan, Gruissen W and Jones R L

Additional information (if any):

Student responsibilities:

1. Class attendance.
2. Study of reading materials as specified by course instructor
3. Self-study

Course reviewers:

1. Dr. B. P. Shaw, Scientist G, Institute of Life Sciences, Bhubaneswar, Odisha
2. Dr. Santan Barthwal, Scientist F, Forest Research Institute, Dehradun, Uttarakhand

Course title: Molecular Microbiology and Immunology			
Course code: BBP ___	**No. of credits: 2**	**L-T-P: 30**-0-0	**Learning hours: 30**
Pre-requisite course code and title (if any): BBP161 Principles of Biochemistry and Biophysics (semester 1)			
Department: Department of Natural and Applied Sciences			
Course coordinator:		**Course instructor**	
Contact details:			
Course type: Core		**Course offered in:** Semester 2	

Course description:

The course is designed to provide students with basic concepts, principles and applications of molecular microbiology and immunology. The course aims to introduce microbial systems to the students and molecular basis of microbial pathogenicity and resistance. Various mechanisms employed by microbes against host immune responses will be covered at a molecular level. The course will provide information on microbial growth patterns and pathogens. Further, basic concepts in immunological responses including adaptive T cell and B cell responses will be described including T cell receptor/MHC interactions and antigen-antibody interactions. The section on molecular assays and techniques will comprehensively provide concepts and principles of major microbiological and immunological methods employed regularly in research laboratories. Finally, through this course, actual concepts and insights within cancer biology and potential anti-cancer therapies are provided.

Course objectives:

1. To introduce students to pathogens and microbial systems that have commercial applications.
2. Providing students with fundamentals of microbial growth and kinetics.
3. Familiarizing students with concepts of microbial drug resistance and the underlying molecular basis.
4. Acquainting students with basic concepts of immunology, with a focus on the molecular bases underlying TCR/pMHC and antibody/antigen interactions
5. Familiarizing students with various molecular techniques employed in microbiology and immunology.
6. Acquainting students with molecular mechanisms underlying cancer development and anti-cancer therapies.

Course contents			
Module **Topic**	**L**	**T**	**P**
Module 1: Microbes and Microbial applications			
Pathogens (classification/structure and function), Infection life cycles of viruses and bacteria, Pathogen host interactions, Viral vectors in gene and cancer therapy, Molecular compounds of microbial origin for agriculture, industry, and pharmaceuticals	**2**	0	0
Module 2: Microbial Kinetics			
Microbial growth and kinetics, batch, and continuous process, Microbial strain improvement for pharmacologically active agents	**3**	0	0
Module 3: Microbial Pathogenicity and Resistance			
Molecular basis of pathogenicity and resistance of bacteria against host immune responses, Drug resistance: *Mycobacterium tuberculosis* (MDR-TB and XDR-TB) and *Streptococcus pneumoniae*, Mechanisms employed by bacterial toxins (cholera, diphtheria, and tetanus), Microbial transformation of antibiotics	**4**	0	0
Module 4: Antibodies and Antigens			
Immunoglobulins- structure and function, Antigenic Determinants (isotype, allotype, idiotype), Antigens (types of antigens, characteristics of an antigen), Adjuvants, Cellular and Humoral immunity, Antigen presentation, TCR, pMHC, Monoclonal antibodies (mAbs), Hybridoma technology, characterization of mAbs through epitope mapping, Immune evasion mechanisms of virulent pathogens, raising antibodies in an animal system, Antibody and Vaccine engineering, Complement system.	**4**	0	0
Module 5: Molecular Assays and Techniques			
5.1: Antibody Titration Techniques: Immuno assay systems, Immuno precipitin reactions, ELISA, RIA, RID,	**3**	0	0
5.2: Immunotechniques: Yeast one hybrid, Yeast two hybrid, TAP- TAG Technology, Synthetic lethal screens, Pull down assays, expression library screening, AFM	**2**		
5.3: Fluorescent antibody techniques: Bimolecular fluorescence complementation (BiFC), Fluorescence resonance energy transfer (FRET) and Fluorescence correlation spectroscopy, Label transfer, Quantitative immunoprecipitation combined with knock-down (QUICK),	**3**		
5.4: Protein-Protein Interaction studies: PPI maps, Protein Chips for diagnostics, SPR, MST, ITC and nanoDSF, Static Light Scattering (SLS)	**3**		
5.5: Immunocytochemistry (cryo-sectioning, resin embedding, freeze-shattering and freeze fracture), Negative Staining, Immunogold labelling, Electron Microscopy	**2**		

Module 6: Cancer Biology			
Tumorigenesis, Invasion and Metastasis, Immunosuppressive mechanisms, Anti-cancer agents and Therapies	**4**		
Total	**30**	**0**	**0**

Evaluation criteria:

1. Test 1 30%
2. Test 2 30%
3. Test 3 (end semester) 40%

Learning outcomes:

1. Acquaintance of basic microbial structure and microbial diversity. Grasp of various microbial systems and applications of microbial compounds of commercial interest (Tests 1, 2 & 3)
2. An insight into the growth patterns of microbes (Test 1 & 2).
3. An understanding of mechanisms behind microbial pathogenicity and resistance. Students will be able to outline key aspects of immune reactions and host responses against pathogens. (Test 2).
4. Grasp of basic concepts of immunology: a. Able to define molecular machinations of cellular and humoral immune responses, roles played by diverse immune cells. b. Understanding of molecular basis of immunological tolerance and autoimmunity. (Test 2).
5. Knowledge of principles underlying the assays and techniques employed in immunology and microbiology (Test 3).
6. A detailed understanding of mechanistics of cancer biology (Test 3).

Pedagogical Approach:

1. Online/Offline teaching.
2. Providing case studies to support the concepts.
3. Peer-reviewed research articles to discuss various modules in the course.
4. Peer-review reading

Skill Set:

1. Analytical skills based on case studies provided.
2. Knowledge of immunological and microbiological applications in various sectors.
3. Knowledge of techniques employed.

Employability:

The course will provide skillsets and knowledge that may play key role to get employed in Universities, R & D industry, Medical centres/Colleges, Research Institutes and Diagnostic centres apart from specialized units like pharma, breweries, dairy and agri sectors.

Materials:
Suggested Readings

1. Schroeder HW Jr, Cavacini L. Structure and function of immunoglobulins. *J Allergy Clin Immunol*. 2010;125(2 Suppl 2):S41-S52. doi:10.1016/j.jaci.2009.09.046
2. Peleg AY, Hogan DA, Mylonakis E. Medically important bacterial-fungal interactions. Nat Rev Microbiol. 2010 May;8(5):340-9. doi: 10.1038/nrmicro2313. Epub 2010 Mar 29. PMID: 20348933.
3. Vermelho AB, Supuran CT, Guisan JM. Microbial enzyme: applications in industry and in bioremediation. *Enzyme Res*. 2012;2012:980681. doi:10.1155/2012/980681
4. Pham JV, Yilma MA, Feliz A, Majid MT, Maffetone N, Walker JR, Kim E, Cho HJ, Reynolds JM, Song MC, Park SR, Yoon YJ. A Review of the Microbial Production of Bioactive Natural Products and Biologics. Front Microbiol. 2019 Jun 20;10:1404. doi: 10.3389/fmicb.2019.01404. PMID: 31281299; PMCID: PMC6596283.
5. Singh S, Kumar NK, Dwiwedi P, Charan J, Kaur R, Sidhu P, Chugh VK. Monoclonal Antibodies: A Review. Curr Clin Pharmacol. 2018;13(2):85-99. doi: 10.2174/1574884712666170809124728. PMID: 28799485.
6. Lu RM, Hwang YC, Liu IJ, Lee CC, Tsai HZ, Li HJ, Wu HC. Development of therapeutic antibodies for the treatment of diseases. J Biomed Sci. 2020 Jan 2;27(1):1. doi: 10.1186/s12929-019-0592-z. PMID: 31894001; PMCID: PMC6939334.
7. Madhurantakam C, Rajakumara E, Mazumdar PA, Saha B, Mitra D, Wiker HG, Sankaranarayanan R, Das AK. Crystal structure of low-molecular-weight protein tyrosine phosphatase from Mycobacterium tuberculosis at 1.9-A resolution. J Bacteriol. 2005 Mar;187(6):2175-81. doi: 10.1128/JB.187.6.2175-2181.2005. PMID: 15743966; PMCID: PMC1064030.
8. Madhurantakam C, Chavali VR, Das AK. Analyzing the catalytic mechanism of MPtpA: a low molecular weight protein tyrosine phosphatase from Mycobacterium tuberculosis through site-directed mutagenesis. Proteins. 2008 May 1;71(2):706-14. doi: 10.1002/prot.21816. PMID: 17975835.
9. Madhurantakam C, Duru AD, Sandalova T, Webb JR, Achour A. Inflammation-associated nitrotyrosination affects TCR recognition through reduced stability and alteration of the molecular surface of the MHC complex. PLoS One. 2012;7(3):e32805. doi: 10.1371/journal.pone.0032805. Epub 2012 Mar 14. PMID: 22431983; PMCID: PMC3303804.
10. Neiers F, Madhurantakam C, Fälker S, Manzano C, Dessen A, Normark S, Henriques-Normark B, Achour A. Two crystal structures of pneumococcal pilus sortase C provide novel insights into catalysis and substrate specificity. J Mol Biol. 2009 Oct 30;393(3):704-16. doi: 10.1016/j.jmb.2009.08.058. Epub 2009 Aug 31. PMID: 19729023.
11. Duru AD, Sun R, Allerbring EB, Chadderton J, Kadri N, Han X, Peqini K, Uchtenhagen H, Madhurantakam C, Pellegrino S, Sandalova T, Nygren PÅ, Turner SJ, Achour A. Tuning antiviral CD8 T-cell response via proline-altered peptide ligand vaccination. PLoS Pathog. 2020 May 4;16(5):e1008244. doi: 10.1371/journal.ppat.1008244. PMID: 32365082; PMCID: PMC7224568.

12. Borek F. The fluorescent antibody method in medical and biological research. *Bull World Health Organ*. 1961;24(2):249-256.
13. Slastnikova TA, Ulasov AV, Rosenkranz AA, Sobolev AS. Targeted Intracellular Delivery of Antibodies: The State of the Art. Front Pharmacol. 2018 Oct 24;9:1208. doi: 10.3389/fphar.2018.01208. PMID: 30405420; PMCID: PMC6207587.
14. Bertram JS. The molecular biology of cancer. Mol Aspects Med. 2000 Dec;21(6):167-223. doi: 10.1016/s0098-2997(00)00007-8. PMID: 11173079.
15. Liu L, Wannemuehler MJ, Narasimhan B. Biomaterial nanocarrier-driven mechanisms to modulate anti-tumor immunity. Curr Opin Biomed Eng. 2021 Dec;20:100322. doi: 10.1016/j.cobme.2021.100322. Epub 2021 Jul 30. PMID: 34423179; PMCID: PMC8372976.
16. Günther G. Multidrug-resistant and extensively drug-resistant tuberculosis: a review of current concepts and future challenges. *Clin Med (Lond)*. 2014;14(3):279-285. doi:10.7861/clinmedicine.14-3-279

Note: Further updated reference and review articles will be provided during the lectures

Additional information (if any): Not Applicable

Student responsibilities:

1. Study of course material as specified by the instructor.
2. Proactive involvement in studying, reviewing and analysing the accessible scientific literature in online/offline modes.

Course reviewers:

1. Prof. Adnane Achour, Structural and Biophysical Immunology, Department of Medicine, Solna, Karolinska Institute, Stockholm, Sweden

2. Dr. Rajakumara Eerappa, Associate Professor, Department of Biotechnology, Indian Institute of Technology, Hyderabad, India

Enclosure 4

Revised course outline of "Climate Change and Law" offered to M.Sc. Climate Science and Policy

Course title: Climate Change and Law			
Course code	**No. of credits:** 2	**L-T-P distribution:** 24- 6-0	**Learning hours**: 30
Pre-requisite course code and title (if any): None			
Department: Natural and Applied Sciences			
Course coordinator (s):		**Course instructor (s):**	
Contact details:			
Course type	Elective		
Course offered in	Semester 2		

Course Description

Climate change is one of the main challenges facing humanity today. It has severe implications for the social, economic, and political life of people around the world. Its ascent as a global and national policy agenda has been driven by the developments in international law. Increasing recognition of the impacts of climate change is also forcing other domains of law to take note of it and respond. Accordingly, the legal foundations of global and national governance systems are going through significant changes. This course is aimed to introduce the students with the processes that govern the legal responses both at the national and international level to this grave crisis. In addition, the course also looks at the impact of this phenomenon on other branches of law like the law of the sea and human rights.

Course objectives

1. To provide an understanding of the international and national laws relating to climate change.
2. To understand the compliance mechanism envisaged under the international legal regime, with a particular reference to India.
3. To analyse the impact of climate change on other branches of law

Course content	**L**	**T**	**P**
Module 1: Introduction	4		
• Sources of International law • Science and law • Key concerns: equity, CBDR & RC, polluter pays principle, precautionary principle, compliance, transparency, legally binding character, climate vs development			
Module 2: Evolution of International Legal Regime on	6	2	

Climate Change			
• Intergovernmental Negotiating Committee-UN Framework Convention on Climate Change – Kyoto Protocol - Paris Agreement- Katowice Package-Glasgow Rulebook • Legal challenges of Top – Down and Bottom – Up approach, NDCs – Enforcement • Montreal Protocol and the Kigali Amendment • International Organizations and Institutions: WMO, IPCC, ICAO, IMO • Current debates: Future of CBDR principle, legality of net-zero emission targets; how legally binding the Paris Agreement is; equity and legal implications of global goal on adaptation; geo-engineering, etc.			
Module 3: Legal response to climate change in select countries	**4**		
• The European Union • United States of America • United Kingdom • Germany			
Module 4: Legal foundation of India's response to climate change	6	4	

• India's obligations under International law and NDCs
• NAPCC and its missions
  o Mitigation: Various acts, regulations, and authorities governing energy sector, urbanization, agriculture, buildings, transport, industry, Forests
  o Adaptation and Resilience: Disaster Management Act (2005), EIA, regulatory requirements/guidelines for resilience/disaster risk reduction in key sectors, Minimum Standards of Environmental Services in Emergencies, and various sectoral acts relevant for adaptation
• SAPCCs and their implementation: strengths and weakness of a federal governance systems Climate action by cities, powers and possibilities of climate action by cities
• Climate action by non-state actors: the limits of CSR
• Does India need a climate change law per se?			

Module 5: Impact on other areas of law and litigation (case studies)	4		
• Climate Change and the Law of the sea: Implications for sovereignty, Marine biodiversity. • Climate change as a human rights issue • Trade issues – Technology Transfer – IPRs • Litigation: Role of NGT			
Total	**24**	**6**	

Evaluation criteria

• Class participation : 10 %
• Term Paper : 25 % (module 1 and 2. Learning outcomes 1 and 2)
• Presentations : 25 % (Module 3 and 4: Learning outcome 3)
• Test 3 : 40% (Module 1-5, Learning outcomes 1-3)

Learning outcomes

By the end of the course, it is expected that the students will:
1. Be familiar with the international legal regime on climate change.
2. Be able to appreciate the concerns raised on the ground of equity and the negotiating position of developing countries.
3. Be able to appreciate the functioning, context, and determinants of effectiveness of legal regimes to address climate change

Materials

Essential texts:

- The United Nations Framework Convention on Climate Change, 1992
- The Kyoto Protocol, 1997
- The Paris Agreement, 2015

Reference Books:

- Bodansky, D., Brunnee, J. and Rajamani, L. (2017), International Climate Change Law, Oxford: OUP.
- Carlarne, Cinnamon P., Gray, Kevin R., and Tarasofsky, Richard (eds) (2016), The Oxford Handbook of International Climate Change Law, Oxford: Oxford University Press.

Module 1.

- Bodansky et al. (2017), Chapters 1-3

- French, D. and Rajamani, L. (2013), "Climate Change and International Environmental Law: Musings on a Journey to Somewhere", *Journal of Environmental Law*, 25 (3): 437-461.

Module 2.

- Bodansky et al. (2017), Chapters 4-7
- Carlarne, Cinnamon (2014), "Delinking International Environmental Law and Climate Change", *Michigan Journal of Environmental and Administrative Law*, 4: 1. Available at: https://repository.law.umich.edu/mjeal/vol4/iss1/1
- Bodansky, D. (2016), "The Legal Character of the Paris Agreement", *Review of European, Comparative and International Environmental Law*, 25 (2): 142-150.

Module 3.

- Siddi, M. (2020), *European Green Deal: assessing its current state and future implementation*, FIIA Working Paper #114, May 2020.
- Skjærseth, J.B. (2021), "Towards a European Green Deal: The evolution of EU climate and energy policy mixes", *Int Environ Agreements* **21,** 25–41. https://doi.org/10.1007/s10784-021-09529-4
- Averchenkova, A., Fankhauser, S. & Finnegan, J.J. (2021), "The impact of strategic climate legislation: evidence from expert interviews on the UK Climate Change Act", *Climate Policy*, 21:2, 251-263, DOI: 10.1080/14693062.2020.1819190
- Mildenberger, M. (2021), "The development of climate institutions in the United States", *Environmental Politics*, 30:sup1, 71-92, DOI: 10.1080/09644016.2021.1947445
- Lockwood, M. (2021), "A hard Act to follow? The evolution and performance of UK climate governance", *Environmental Politics*, 30:sup1, 26-48, DOI: 10.1080/09644016.2021.1910434
- Flachsland, C. & Levi, S. (2021), "Germany's Federal Climate Change Act", *Environmental Politics*, 30:sup1, 118-140, DOI: 10.1080/09644016.2021.1980288
- Mehryar, S. & Surminski, S. (2021), "National laws for enhancing flood resilience in the context of climate change: potential and shortcomings", *Climate Policy*, 21:2, 133-151, DOI: 10.1080/14693062.2020.1808439

Websites:

1. www.congress.gov
2. https://ec.europa.eu
3. www.legislation.gov.uk

4. www.bundesregierung.de

Module 4

- Dubash, N.K., Khosla, R., Kelkar, U., and Lele, S. (2018), "India and Climate Change: Evolving Ideas and Increasing Policy Engagement", *Annual Review of Environment and Resources,* 43:1, 395-424.
- Upadhyaya, P., Shrivastava, M.K., Gorti, G., & Fakir, S. (2021), "Capacity building for proportionate climate policy: Lessons from India and South Africa", *International Political Science Review,* 42(1):130-145. doi:10.1177/0192512120963883
- Pillai, A.V. & Dubash, N.K. (2021), "The limits of opportunism: the uneven emergence of climate institutions in India", *Environmental Politics*, 30: sup1, 93-117, DOI: 10.1080/09644016.2021.1933800
- Pahuja, N., Pandey, N., Mandal, K., & Bandyopadhyay, C. (2014). *GHG Mitigation in India: An Overview of the Current Policy Landscape*, Working Paper. Washington, DC: World Resources Institute. Available online at http://www.wri. org/publication/ghg-mitigation-ind-policy.
- Dutta, M. (2021), *Adapting to Climate Change from a Gender and Human Rights Law Perspective: A Policy Review of India,* Available at SSRN: https://ssrn.com/abstract=3993409
- Divan, S., Yadav, S. & Sawhney, R.S. (2021), *Legal Opinion: Directors' obligations to consider climate change-related risk in India,* available at https://ccli.ubc.ca/wp-content/uploads/2021/09/CCLI_Legal_Opinion_India_Directors_Duties.pdf
- Gogoi, E. (2017), *India's state action plans on climate change: towards meaningful action*, Oxford Policy Management, New Delhi
- GoI (2000), *National Agricultural Policy,* Government of India, New Delhi
- GoI (2005), *National electricity policy,* Ministry of Power, Government of India, New Delhi. Available at https://powermin.nic.in/en/content/national-electricity-policy
- GoI (2007), *National urban housing and habitat policy,* Ministry of Housing & Urban Pverty Alleviation, Government of India, New Delhi. Available at https://nhb.org.in/Urban_Housing/HousingPolicy2007.pdf
- GoI (2008), *National Water Mission under National Action Plan on Climate Change*, Ministry of Water Resources, Government of India. Available at http://mowr.gov.in/sites/default/files/Mission_Doc_Vol22880755143_0.pdf
- GoI (2010), *National mission for a green India*, Ministry of Environment and Forests, Government of India. Available at http://www.indiaenvironmentportal.org.in/files/green-india-mission.pdf
- GoI (2010), *National mission for sustainable agriculture*, Department of Agriculture

and Cooperation, Ministry of Agriculture, Government of India. Available at http://agricoop.nic.in/sites/default/files/National%20Mission%20For%20Sustainable%20Agriculture-DRAFT-Sept-2010.pdf

- GoI (2010), *National mission for sustaining the Himalayan Ecosystem under National Action Plan on Climate Change (NAPCC),* Department of Science and Technology, Ministry of Scince and Technology, Government of India, New Delhi. Available at http://www.knowledgeportal-nmshe.in/Pdf/NMSHE_MissonDocument.pdf
- GOI (2011), *Disaster management in India*, Ministry of Home Affairs. Government of India
- GoI (2012), *National water policy,* Ministry of Water Resources, Government of India, New Delhi. Available at http://mowr.gov.in/sites/default/files/NWP2012Eng6495132651_1.pdf
- GOI (2015), *India's intended nationally determined contribution*. Press Information Bureau, Government of India
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Journals for further references

- Journal of International Environmental Agreements
- Climate Policy
- Climate Change and Law Review
- American Journal of International Law

Employability: This course exposes the students to the legal foundations of policy and action on climate change, as well as the political and economic drivers of legal framework. The students are well prepared for the jobs related to policy research and compliance.

Student responsibilities

Attendance, pre-reads, critical engagement, feedback, discipline, etc.

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