*(Revised based on the inputs in the standing Committee meeting on 24th August 2018)*

# UNIVERSITY OF DELHI

## MASTER OF ZOOLOGY

## (MSZOOL)

**(**Effective from Academic Year 2018-19)

# PROGRAMME BROCHURE

XXXXX Revised Syllabus as approved by Academic Council on XXXX, 2018 and

Executive Council on YYYY, 2018

**(Head of the Department)**
**4th September 2018**

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## I. About the Department

The Department of Zoology was established as a premier center of teaching and research in animal sciences in 1947. In 1963, it was recognized as the Centre for Advanced Studies (CAS) and continues to enjoy this status by special assistance of the UGC-SAP program. UGC extended its CAS status in 2011 by providing special assistance for another five years. The department has created a state of the art central-instrument facility through the generous support of the University and also from DST-FIST program grants.

In the 70 years of its existence, the department is credited for producing several post-graduate students and awarded nearly 550 doctoral degrees. Its alumni are doing exceptionally well mainly as teachers and scientists at various universities and research laboratories in India and abroad. The academic training imparted to the department's M.Sc. students, equips them to enter doctoral programs of leading institutes in the country and abroad.

The current research and teaching in the Department include diverse aspects of Zoology with a balance of organismic and reductionist biology. It offers teaching and research programmes in the diverse areas, such as, Animal Physiology, Entomology, Fish Biology, Immunology, Developmental Biology, Cell Signaling, Cell Biology, Radiation Biology, Reproductive Biology, Endocrinology, Genomics, Metagenomics and Cancer Biology. Apart from teaching, the faculty has been publishing papers in peer-reviewed research journals. The department practices interdisciplinary research.

The vision of the department is to develop a world-class center of excellence in education, training & research in the field of Zoology where teaching and research encrust detailed understanding from microbes to human. Therefore, the department aims to impart holistic understanding of Zoology by "redefining Zoology" to students of every age so that they develop interest in Science. It also aims to develop teaching and research programmes that have relevance to the society and employability. To further strengthen teaching and research in the Department, an extensive renovation and up-gradation of teaching and research laboratories have recently been undertaken. The M.Sc. programme is being revised under CBCS scheme of UGC to meet the expectations of students and to fulfill the vision and mission of the Department. The department has made remarkable strides during the past 70 years and is committed to continue working hard for excellence in Science.

# II. Introduction to CBCS (Choice Based Credit System)

## Choice Based Credit System:

The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill-based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Grading system provides uniformity in the evaluation and computation of the Cumulative Grade Point Average (CGPA) based on student's performance in examinations which enables the student to move across institutions of higher learning. The uniformity in evaluation system also enable the potential employers in assessing the performance of the candidates.

## Definitions:

(i) 'Academic Programme' means an entire course of study comprising its programme structure, course details, evaluation schemes etc. designed to be taught and evaluated in a teaching Department/Centre or jointly under more than one such Department/ Centre

(ii) 'Course' means a segment of a subject that is part of an Academic Programme

(iii) 'Programme Structure' means a list of courses (Core, Elective, Open Elective) that makes up an academic programme, specifying the syllabus, credits, hours of teaching, evaluation and examination schemes, minimum number of credits required for successful completion of the programme etc. prepared in conformity to University rules, eligibility criteria for admission

(iv) 'Core Course' means a course that a student admitted to a particular programme must successfully complete to receive the degree and which cannot be substituted by any other course

(v) 'Elective Course' means an optional course to be selected by a student out of such courses offered in the same or any other Department/Centre

(vi) 'Open Elective' means an elective course which is available for students of all programmes, including students of same department. Students of other Department will opt these courses subject to fulfilling of eligibility of criteria as laid down by the Department offering the course.

(vii) 'Credit' means the value assigned to a course which indicates the level of instruction; One-hour lecture per week equals 1 credit, 2 hours practical class per week equals 1 credit. Credit for a practical could be proposed as part of a course or as a separate practical course

(viii) 'SGPA' means Semester Grade Point Average calculated for individual semester.

(ix) 'CGPA' is Cumulative Grade Points Average calculated for all courses completed by the students at any point of time. CGPA is calculated each year for both the semesters clubbed together.

(x) ‘Grand CGPA’ is calculated in the last year of the course by clubbing together of CGPA of two years, i.e., four semesters. Grand CGPA is being given in Transcript form. To benefit the student a formula for conversation of Grand CGPA into %age marks is given in the Transcript.

**III. M.Sc. Zoology Programme Details:**

**Programme Objectives (POs):**

The programme **M.Sc. in Zoology** aims to equip students with recent advances in Zoology from organismic to reductionist biology. It also aims to empower students to understand the challenges of society and the country that falls into the realms of Zoology, such as Aquaculture, Reproductive health, Behavior and Biological time keeping, Cancer Biology, Microbiome and their roles in health and diseases, Bioremediation of pollutants and pesticides, etc. It also offers students to a series of elective courses so that they can choose to specialize in the specific area of their interests in Zoology.

Keeping the true spirit of choice-based credit system scheme, close to 40% of the total credits are offered as elective courses. First and second semester courses are offered as core-courses, and in that 33% credits are assigned for lab work and hands-on experience. At third semester, to choose two elective courses, a student has a bouquet of sixcourses divided in two groups. The open elective has been chosen to attract students from diverse interdisciplinary areas of sciences, such as Anthropology, Environmental studies, Biomedical Sciences, etc. This course is designed to ignite the inquisitive mind to enter in to research in interdisciplinary areas. The fourth semester offers a total of 16 elective courses, which for logistics of programme management, are divided in to four streams, where a student has to choose a stream. In the fourth semester also, the major emphasis is on skill-based training into socially relevant areas of Zoology.

These courses are open for admission to students from Zoology (Hons.) to Life Sciences and Biomedical sciences if they have studied Zoology and Chemistry as generic elective at undergraduate level under CBCS scheme.

**ProgrammeSpecific Outcomes (PSOs):**

It is expected that a student after successfully completing four semesters of **M.Sc. in Zoology programme** would sufficiently be skilled and empowered to solve the problems in the realms of Zoology and its allied areas. They would have plethora of job opportunities in the education, environment, agriculture-based, and health related sectors. The bright and ignited mind may enter into research in the contemporary areas of Zoological/Biological Sciences. The broad skills and the deeper knowledge in the field would make them highly successful and excellent researcher in advanced areas of research in the Biological sciences.

## Programme Structure:

The **M.Sc. in Zoology**programme is a two-year course divided into four-semester. A student is required to complete **94** credits for the completion of course and the award of degree.

| | | **Semester** | **Semester** |
|---|---|---|---|
| **Part – I** | First Year | Semester I | Semester II |
| **Part – II** | Second Year | Semester III | Semester IV |

### Course Credit Scheme

| **Semester** | **Core Courses** | | | **Elective Course** | | | **Open Elective Course** | | | **Total Credits** |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of papers | Credits (L+P) | **Total Credits** | No. of papers | Credits (L+P) | **Total Credits** | No. of papers | Credits (L+P) | **Total Credits** | |
| I | 5 | 16L+6P | **22** | - | - | **-** | - | - | **-** | **22** |
| II | 5 | 16L+6P | **22** | - | - | **-** | - | - | **-** | **22** |
| III | 2 | 8L+4P | **12** | 2 | 8L+ 4P | **12** | 1 | 4L | **4** | **28** |
| IV | - | - | **-** | 5 | 16L+6P | **22** | - | - | **-** | **22** |
| **Total Credits for the Course** | 12 | 40L+18P | **56** | 6 | 24L+10P | **34** | 1 | 4L | **4** | **94** |

- For each Core and Elective Courses (4 credit each), there will be 4 lecture hours of teaching per week. For practical (1 credit) will be of two hours of practical every week. Therefore, for a 6 credit practicals, there will be 12 hours of practicals every week.
- Open Electives will be of 4 credits.

# Semester wise Details of M.Sc. Zoology Course

**Paper Codes**: The first two letters (MS) in a paper code defines as M.Sc. course, the ZOOL defines as a course of Zoology, and the last letter as C, E, P or OE defines as core, elective, practical or open elective, respectively. The First numeral defines the semester and the remaining two numerals defines stream and the paper number.

| **Semester I** | | | | |
|---|---|---|---|---|
| **Number of core courses** | **Credits in each core course** | | | |
| Course | Theory | Practical | Tutorial | Credits |
| MS ZOOLC-101 **Genetics and Cytogenetics** | 4 | - | - | 4 |
| MS ZOOLC-102 **Principles of Gene Manipulation** | 4 | - | - | 4 |
| MS ZOOLC-103 **Comparative Animal Physiology** | 4 | - | - | 4 |
| MS ZOOLC-104 **Metabolism: Concepts and Regulation** | 4 | - | - | 4 |
| MS ZOOLC-105P **Core Practical 1** | - | 6 | | 6 |
| Core course 5 (total number) | 16 | 6 | | 22 |
| **Total credits in I Semester core course** | **22** | | | |
| | | | | |
| **Semester II** | | | | |
| **Number of core courses** | **Credits in each core course** | | | |
| Course | Theory | Practical# | Tutorial | Credits |
| MS ZOOLC-201 **Developmental Biology** | 4 | - | - | 4 |
| MS ZOOLC-202 **Systematics, Biodiversity and Evolution** | 4 | - | - | 4 |
| MS ZOOLC-203 **Immunology** | 4 | - | - | 4 |
| MS ZOOLC-204 **Molecular Cell Biology** | 4 | - | - | 4 |
| MS ZOOLC-205P **Core Practical 2** | - | 6 | - | 6 |
| Core course 5 (total number) | 16 | 6 | | 22 |
| **Total credits in II semester core course** | **22** | | | |

| **Semester III** | | | | |
|---|---|---|---|---|
| **Number of core courses** | **Credits in each core course** | | | |
| Course | Theory | Practical | Tutorial | Credits |
| MS ZOOLC-301<br>**Principles of Ecology** | 4 | 2 | - | 6 |
| MS ZOOLC-302<br>**Computational Biology, Biostatistics and Bioinformatics** | 4 | 2 | - | 6 |
| Core course 2 (total number) | 8 | 4 | | 12 |
| **Total credits in core course** | **12** | | | |
| **Number of elective courses**<br>*A student has to choose one elective from each of the following two groups* | Credits in each Elective course | | | |
| Credits in each elective course | Theory | Practical | Tutorial | Credits |
| **Group-A**<br>**MS ZOOLE- 303 or 304 or 305**<br><br>MS ZOOLE-303 **Parasitology**<br>or<br>MS ZOOLE-304 **Chronobiology**<br>or<br>MS ZOOLE-305 **Protein Structure, Function and Evolution** | 4 | 2 | - | 6 |
| **Group-B**<br>**MS ZOOLE 306 or 307 or 308**<br><br>MS ZOOLE-306 **Structure and Function of Genes**<br>or<br>MS ZOOLE-307 **Animal Behavior**<br>or<br>MS ZOOLE-308 **Comparative Endocrine Physiology** | 4 | 2 | - | 6 |
| **Total credits in 2 elective courses** | **12** | | | |
| | | | | |

| **Number of Open Electives** | Credits in each open elective | | | |
|---|---|---|---|---|
| | Theory | | | Credits |
| Open Elective<br>MS ZOOLOE-309<br>**Behavior of Social Animals** | 4 | - | - | 4 |
| **Total credits in 1 open elective** | **4** | | | |
| **Total credits in III Semester (Core, Elective and open Elective) - 28** | | | | |
| | | | | |
| **Semester IV** | | | | |
| **Number of Elective courses**<br>(@- *a student has to choose one of the four elective streams and each stream has five papers*) | **Credits in each elective course@** | | | |
| Elective Courses | Theory | Practical | Tutorial | Credits |
| **Stream -1 Entomology**<br>MS ZOOLE-4101**Insect Diversity, Society and Evolution**<br>MS ZOOLE-4102**Insect Physiology**<br>MS ZOOLE-4103**Insect Toxicology and Ecology**<br>MS ZOOLE-4104**Agricultural & Medical Entomology**<br>MS ZOOLE-4105P **Practicals in Entomology** | 16 | 6 | - | 22 |
| **Stream -2 Fish Biology**<br>MS ZOOLE-4201**Diversity and Behaviour of Fishes**<br>MS ZOOLE-4202**Fish Physiology**<br>MS ZOOLE-4203**Aquatic Resources and their Conservation**<br>MS ZOOLE-4204**Aquaculture**<br>MS ZOOLE-4205P **Practicals in Fish Biology** | 16 | 6 | - | 22 |
| **Stream -3 Genomes and Evolution**<br>MS ZOOLE-4301 **Genomics**<br>MS ZOOLE-4302**Microbiome**<br>MS ZOOLE-4303 **RNA Biology**<br>MS ZOOLE-4304 **Epigenetics and** | 16 | | - | 22 |

| | | | | |
|---|---|---|---|---|
| **trans-generational Inheritance**<br>MS ZOOLE-4305P **Practicals in Genomes and Evolution** | | 6 | | |
| **Stream -4 Molecular Endocrinology and Reproduction**<br>MS ZOOLE-4401 **Neuroendocrinology**<br>MS ZOOLE-4402 **Environment, Epigenetics and Hormone action**<br>MS ZOOLE-4403**Gamete Biology**<br>MS ZOOLE-4404**Biology of Pregnancy, Parturition and Lactation**<br>MS ZOOLE-4405P **Practicals in Molecular Endocrinology and Reproduction** | 16 | 6 | - | 22 |
| Core course 4 (total number) | 16 | 6 | | 22 |
| **Total credits in IV semester core course** | **22** | | | |
| | | | | |
| **TOTAL CREDIT I+II+III+IV Semesters: 22+22+28+22= 94 credits** | | | | |

## List of Elective Course (wherever applicable to be mentioned area wise)

**1. List of Electives and Open Elective in 3rd Semester:**

**Group-A**

MS ZOOLE-303 Parasitology

MS ZOOLE-304 Chronobiology

MS ZOOLE-305 Protein Structure, Function &Evolution

**Group–B**

MS ZOOLE-306 Structure and Function of Genes

MS ZOOLE-307 Animal Behavior

MS ZOOLE-308 Comparative Endocrine Physiology

Open Elective

MS ZOOLOE 309 Behavior of Social Animals

In the 3rd Semester, a student has to choose two subject-based elective papers, one from each group of Group A –(MS ZOOLE-303 or MS ZOOLE-304 or MS ZOOLE-305), and Group-B (MS ZOOLE-306 or MS ZOOLE-307 or MS-ZOOLE-308).

A student has also to choose an open elective from other interdisciplinary department of their interest. The Zoology open elective MS ZOOLOE-309 shall be open to students from any stream of science.

2. **List of Elective in 4th Semester:**

**Stream -1 Entomology**

MS ZOOLE-4101 Insect Diversity, Society and Evolution
MS ZOOLE-4102 Insect Physiology
MS ZOOLE-4103 Insect Toxicology and Ecology
MS ZOOLE-4104 Agricultural & Medical Entomology
MS ZOOLE-4105P Practicals in Entomology

**Stream -2 Fish Biology**

MS ZOOLE-4201 Diversity and Behaviour of Fishes
MS ZOOLE-4202 Fish Physiology
MS ZOOLE-4203 Aquatic Resources and their Conservation
MS ZOOLE-4204 Aquaculture
MS ZOOLE-4205P Practicals in Fish Biology

**Stream -3 Genomes and Evolution**

MS ZOOLE-4301 Genomics
MS ZOOLE-4302 Microbiome
MS ZOOLE-4303 RNA Biology
MS ZOOLE-4304 Epigenetics and trans-generational Inheritance
MS ZOOLE-4305P Practicals in Genomes and Evolution

**Stream -4 Molecular Endocrinology and Reproduction**

MS ZOOLE-4401 Neuroendocrinology
MS ZOOLE-4402 Environment, Epigenetics and Hormone action
MS ZOOLE-4403 Gamete Biology
MS ZOOLE-4404 Biology of Pregnancy, Parturition and Lactation
MS ZOOLE-4405P Practicals in Molecular Endocrinology and Reproduction

In the fourth semester, a student has to choose one of the four streams. Each stream (**Stream - Entomology** - MS ZOOLE-4101 to 4105; **Stream - Fish Biology**- MS ZOOLE-4201 to 4205; **Stream - Genomes and Evolution** - MS ZOOLE-4301 to 4305; **Stream - Molecular Endocrinology & Reproduction**-MS ZOOLE – 4401 to 4405) has five papers.

3. The Selection of elective papers in 3rd and 4th Semesters would be based on merit (performance in the Part I Examinations).
4. **Dissertation** - For logistics of limited resources and limited faculty members, the dissertation in optional as an add-on course. A student may opt to do a dissertation in the research laboratory of any of the Faculty members. This will be purely on mutual agreement between the student and the Faculty member. Upon successful completion of the dissertation (as certified by the concerned faculty member), the department would issue a certificate to the student.

**Selection of Elective/Open elective Courses:**

1. **Elective courses in Zoology**- The number seats in each elective would be limited and will be announced before the commencement of the course in each year. The Selection of elective papers in 3rd and 4th Semesters would be based on merit (performance in the First Semester Examination).

2. **Open Elective Course in Zoology** - There shall be total of 92 seats in open elective in Zoology. This number is the maximum intake of students in M.Sc. Zoology. Students of Faculty of science who have studied Biology at least at the level of +2 can opt for Open Elective in Zoology. The selection of students shall be based on the merit prepared based on their marks obtained in the M.Sc. First semester.

**Teaching:**

The faculty of the Department is primarily responsible for organizing lectures for **M.Sc. in Zoology**. There shall be 90 instructional days excluding examination in a semester.

**Eligibility for Admissions:**

As discussed and decided by the Courses Committee at the Faculty of Science. A total 92 seats are divided equally into two modes of admissions, merit-based (for students who have passed B.Sc. Zoology (Hons.) course from the University of Delhi only, and entrance test based (open to B.Sc. Zoology (Hons.) students, B.Sc. Biological Sciences and Life Sciences students from University of Delhi or other University as recognized by the UGC and have taken Zoology and Chemistry as two of their courses.

The policy of reservation as per the Govt. of India applies on these total seats. As per the rules of University of Delhi, there are supernumerary seats also available for admission. Please refer to the rules of University of Delhi for seats and the procedure for admission in these categories.

**Assessment of Students' Performance and Scheme of Examinations:**

1. English shall be the medium of instruction and examination.
2. Assessment of students' performance shall consist of:

Examinations shall be conducted at the end of each semester as per the Academic Calendar notified by the University of Delhi.

A. Each 4 credit course will carry 100 marks and will have two components (i) Internal assessment for 30 marks and end-semester examination for 70 marks:

| | | |
|---|---|---|
| (i) | Internal assessment | 30 marks |
| | (a) Examination/Assignments/Seminar etc. | 25marks |
| | (b) Attendance | 05 marks |
| (ii) | End-semester Examination: | 70 marks |

B. Each four credit theory course shall be evaluated for 100 marks at the end semester examination.
C. Each two and six credit practical course shall be evaluated at the end-semester examination for 50 and 150 marks respectively.
D. Internal assessment will be broadly based on attendance in Theory and Practicals (5 marks), assignments, seminars and tests in the theory component (25 marks). These criteria are tentative and could be modified based on guidelines approved by the academic council.
E. Examinations for courses shall be conducted only in the respective odd and even Semesters as per the Scheme of Examinations. Regular as well as Ex-students shall be permitted to appear/re-appear/improve in courses of Odd Semesters only at the end of Odd Semesters and courses of Even Semesters only at the end of Even Semesters.

## Pass Percentage & Promotion Criteria:

As per the rules of University of Delhi.

## Part I to Part II Progression:

As per the rules of the University of Delhi

## Conversion of Marks into Grades:

As per the rules of the University of Delhi

## Grade Points:

Grade point table as per University Examination rule

## CGPA Calculation:

As per University Examination rule.

## SGPA Calculation:

## Grand SGPA Calculation:

## Conversion of Grand CGPA into Marks

As notified by competent authority the formula for conversion of Grand CGPA into marks is:Final %age of marks = CGPA based on all four semesters × 9.5

## Division of Degree into Classes:

Post Graduate degree to be classified based on CGPA obtained into various classes as notified into Examination policy.

## Attendance Requirement:

No student shall be considered to have pursued a regular course of study unless he/she is certified by the Head of the Department of Zoology, University of Delhi, to have attended 75% of the total number of lectures and seminars conducted in each semester, during his/her course of study. Provided that he/she fulfils other conditions, the Head, Department of Zoology, may permit a student to the next Semester who falls short of the required percentage of attendance by not more than 10% of the lectures and seminars conducted during the Semester.

**Span Period:**

No student shall be admitted as a candidate for the examination for any of the Parts/Semesters after the lapse of **four** years from the date of admission to the Part-I/Semester-I of the **M.Sc. Zoology** Programme.

## Guidelines for the Award of Internal Assessment Marks in M.Sc. Zoology Programme (Semester Wise)

Internal assessment will be broadly based on attendance in Theory and Practicals (5 marks), assignments, seminars and tests in the theory component (25 marks). These criteria are tentative and could be modified based on guidelines approved by the academic council.

# IV: Course Wise Content Details for M.Sc. in Zoology Programme:

## MASTER OF ZOOLOGY

**Semester –I**

**Core Papers**

**MS ZOOLC-101: Genetics and Cytogenetics**

**Course Objectives:**

Genetics and Cytogenetics is offered as a core course that provides fundamental knowledge of how organisms, populations and species evolve. Apart from Mendel's laws and basic genetics, at Master's level, this course will provide some of the most incisive analytical approaches that are now being used across the spectrum of the biological disciplines.

Cytogenetics will impart knowledge about the human chromosome constitution that would help in applying basic principles of chromosome behavior to disease context.

Overall, this course will highlight extension of Mendelian Genetics, dosage compensation, evolution of the concept of gene and its amalgamation with molecular biology and study of genetic diseases.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Mendel's laws and their chromosomal basis**; extension of Mendel's principles: allelic variation and gene function- incomplete dominance and co-dominance, allelic series, testing gene mutations for allelism; gene action- from genotype to phenotype– penetrance and expressivity, gene interaction, epistasis, pleiotropy. | 4 |
| **Unit 2.** | **Nature of the gene and its functions**: evolution of the concept of the gene, fine structure of gene (rII locus); | 4 |
| **Unit 3.** | **Linkage, Crossing Over and Chromosome Mapping in Eukaryotes**: Methods of gene mapping: 3- point test cross in *Drosophila*, pattern of inheritance by pedigree analysis and gene mapping, Human genome and mapping. | 8 |
| **Unit 4.** | **Gene mutation, DNA repair andRecombination**: types of gene mutations, methods for detection of induced mutations; P- element insertional mutagenesis in *Drosophila;* DNA damage, repair and recombination. | 10 |
| **Unit 5.** | **Regulation of Gene Expression:**Regulation of gene activity in *lac* and *trp* operons of *E. coli*.;General introduction to gene regulation in eukaryotes at transcriptional and posttranscriptional levels; Chromatin organization and gene expression, transcription factors, enhancers and silencers, non coding genes. | 10 |

| | | |
|---|---|---|
| **Unit 6.** | **Mechanisms of sex determination and Dosage Compensation**: Human, *Drosophila*and*C. elegans*. | 8 |
| **Unit 6.** | **Genetic analysis of complex traits** - complex pattern of inheritance, quantitative traits, threshold traits. | 6 |
| **Unit 7.** | **Human genetics**- Chromosome banding, karyotype and nomenclature of metaphase chromosome; chromosomal anomalies in malignancy (chronic myeloid leukemia, Burkitt's lymphoma, retinoblastoma and Wilms' tumor); oncogenes and tumor suppressor genes- genetic pathways to cancer. | 10 |

**Suggested Literature:**

1. Principles of Genetics, Snustad and Simmons, John Wiley & Sons, USA [Latest edition] .
2. Modern Genetic Analysis: Integrating Genes and Genomes, Griffiths, J.F., Gilbert, M., Lewontin, C. and Miller, W. H. Freeman and Company, New York, USA[Latest edition] .
3. Genetics, J. Russell, Benjamin-Cummings Publishing Company, San Francisco, California, USA [Latest edition] .

**Course Learning Outcomes:**

- Genetics and Cytogenetics course will open up several avenues for students in terms of research and employability.
- Genetics has made extensive use of model organisms**,** many of which will be used to teach this course. By observing genetic mutations in *Drosophila*, students can correlate phenotype with genotype, understand genetic interaction and their molecular basis.
- Students will be able to set hands on genetic crosses to understand recessive and dominant, segregation, pattern of inheritance and finally evaluating statistical significance by counting the progeny as statistical analysis provides crucial. insight into many biological processes.
- Students will learn how genetic information is passed on in eukaryotes and prokaryotes, how genes work together in a complex manner in biological system and any alteration can lead to major phenotypic change.
- Students will appreciate the concept of epigenetics as a key mechanism of regulation of gene expression steering development and cell fate that can ultimately be affected in disease condition.

## MS ZOOLC-102: Principles of Gene Manipulation

### Course Objectives:

Major objective of this core paper is to introduce to the students contemporary molecular techniques for manipulation of genome that could assist them towards advanced understanding of biological processes in broad range of host organisms. Lectures will specifically address the historical standard techniques, gradual evolution and context-dependent medications of molecular techniques for their extended use. The student should be able to understand standard and system-specific gene manipulation approaches ranging from bacteria to mammals. A prior exposure to recombinant DNA technology at undergraduate level is desirable for accelerated learning.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Basic recombinant DNA techniques**: cutting and joining DNA molecules, restriction modification systems, various enzymes used in recombinant DNA technology, restriction maps and mapping techniques; nucleic acid probes, blotting techniques, DNA fingerprinting, footprinting, methyl interference assay. Polymerase chain reaction–methods and applications. | 15 |
| **Unit 2.** | **Basic biology of vectors and cloning strategies**: plasmids, phages, single stranded DNA vectors, high capacity vectors, retroviral vectors, expression vectors and other advanced vectors in use. Gene cloning strategies: methods of transforming E. coli and other cells with rDNA; methods of selection and screening of transformed cells; construction of genomic and cDNA libraries; strategies of expressing cloned genes; phage display. | 15 |
| **Unit 3.** | **Sequencing methods and site directed mutagenesis:**Principles of DNA sequencing, automated sequencing methods; synthesis of oligonucleotides, primer design; micro-arrays; changing genes-directed evolution, protein engineering. | 15 |
| **Unit 4.** | **Manipulating genes in animals:** gene transfer to animal cells, genetic manipulation of animals, transgenic technology, application of recombinant DNA technology; genetically modified organisms: gene knockouts, mouse disease models, gene silencing, gene therapy, somatic and germ- line therapy. | 15 |

### Suggested Literature:

1. Recombinant DNA: Genes and Genomics – a short course, Watson et al., W. H. Freeman and Company, New York, USA [Latest edition].
2. Principles of Gene Manipulation and Genomics, Primrose, S. B. and Twyman, R.M., (7th Ed. 2006), Blackwell Publishing, West Sussex, UK.
3. Molecular Biotechnology: Principles and application of recombinant DNA, Bernard R. and Jack, ASM Press, Herndon, USA [Latest edition].

**Course Learning Outcomes:**

After successful completion of the course the candidate should be able to design and comprehend experimental strategies for alteration of genes and gene products in variety of organisms.

## MS ZOOLC-103: Comparative Animal Physiology

### Course Objectives:

Animal physiology is the study of animal structure and function. This course on '**Comparative Animal Physiology'** helps understand how animals work at all levels, ranging from individual cells to the whole integrated organism. The scope of physiology includes elucidation of the function of all cells in all organs and all animals related to nervous, respiratory, circulatory and other physiological systems. This course especially focuses on the modifications/adaptations found in different physiological systems of various organisms across the animal kingdom. The course also has a strong lab component, where certain classical and interesting exercises will be conducted to answer various practical queries in animal physiology.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Internal Transport and Gas Exchange**: Systems of circulation, Peripheral circulation, Regulation of heart beat and blood pressure, Transport and exchange of gases, Neural and chemical regulation of respiration, Gas transfer in air and water, Gas exchangers, Circulatory and respiratory responses to extreme conditions, Acid –base balance, Regulation of body pH. | 10 |
| **Unit 2.** | **Adaptations to Stress**: basic concept of environmental stress, acclimation, acclimatization, avoidance and tolerance, stress and hormones. Osmoregulation- Osmoregulation in aquatic and terrestrial environments, Extra-renal osmoregulatory organs, Patterns of nitrogen excretion. Thermoregulation- Heat balance in animals, Adaptations to temperature extremes, torpor, Aestivation and hibernation, Counter current heat exchangers. | 15 |
| **Unit 3.** | **Sensing the Environment&Coordination**:Neuroanatomy and integrated function of the nervous system; Photoreception, Chemoreception, Mechanoreception; Echolocation, Endogenous and exogenous biological rhythms; Chromatophores- Types and Functional Modifications vis-a-via different animals (Invertebrates & Vertebrates) & control; Behavioural significance and its application; Bioluminescence- Phenomenon dynamics (Luciferin-Luciferase reaction); Occurrence in different groups of animal kingdom, Types (Blue & Red), functional significance and its application in mankind. | 15 |
| **Unit 4.** | **Muscle physiology**: Types of muscle, structure, properties, function &control, Muscle Energetics, Muscle Adaptations in invertebrates and vertebrates; Electric organs **(**myogenic lineage)- Electroplaxes, Electric discharge, Organogenesis, Electroception, functional significance in animals | 15 |
| **Unit 5.** | **Feeding:** Patterns, Behaviour, mechanisms and their control, effect of starvation. | 5 |

**Suggested Literature:**

1. General and Comparative Animal Physiology, Hoar W. S. (ed.), Prentice Hall, India.
2. Comparative Physiology (Handbook of Physiology): Vol. 1, 2, Dantzler, W.H. (ed.) Oxford University Press, New York, USA.
3. Animal Physiology: Adaptation and Environmental, Nelson K. S. (ed.) Cambridge University Press, Cambridge, UK.
4. Comparative Animal Physiology, Prosser,C.L. & Brown Jr.,F.A.(ed.), Saunders.
5. Eckert: Animal Physiology 5th Ed by Randall, David, Burggern, Warren, French, Kathleen (2001)

**Course Learning Outcomes:**

- After going through this course on '**Comparative Animal Physiology',** the studentshave a good understanding of how invertebrate and vertebrate animals work and how these animals' biology is influenced by the different environments of their niches. The students will be able to explore an original query in animal physiology. The students will appreciate evolutionary changes and environmental adaptations in different taxa of invertebrates and vertebrates.

## MS ZOOLC-104: Metabolism – Concepts and Regulation

**Course Objectives:**

The paper Metabolism: Concept and Regulation is designed as an advance course for understanding the interaction, network and regulation of certain important metabolic pathways and their roles in health and diseases. In the present context, manifestations of all non-communicable diseases, such as Cancer, Cardio Vascular disorder, Diabetes, Arthritis, Alzheimer's, even aging etc. are due to metabolic failure and reprogramming of metabolic pathways. The course also explains the interplay and energetics, catalysis and design of living systems. It is designed for students who have already taken up the courses and elementary biochemistry and macromolecular structures at the undergraduate level.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Energetics and Design of Living Systems:**The living state, metabolism as the defining characteristic of living organisms, molecular approach to understanding life forms and living processes, Energetics (second law of thermodynamics, Free Energy and standard free energy change), Reducing power and Redox potential, Nernst equation, synthesis of ATP, structure and function of electron transport chain and synthesis of ATP through Fo-F1 ATP synthase. | 15 |
| **Unit 2.** | **Catalysis and its Regulation:**Nature of enzymes – kinetics, reaction mechanism of chymotrypsin and lysozyme, Inhibition of Enzyme activity, regulation of enzyme activity. | 15 |
| **Unit 3.** | **Metabolic Pathways and its Network:**A broad outline of metabolic pathways and their linkage, metabolism of primary metabolites – monosaccharaides, lipids, essential amino acids and nucleotides. | 20 |
| **Unit 4.** | **Metabolic Reprogramming:** Dynamic state of body constituents, experimental approaches to study metabolism, Metabolic basis of nutrition, metabolic basis of specialized tissue function, metabolic disorders, metabolic basis of diagnostics, metabolism and adaption with one example, regulation of metabolism at molecular, cellular and organismic levels, enzymes and receptors as drug targets. | 10 |

**Suggested Literature:**

1. Lehningers Principles of Biochemistry, Nelson and Cox, Sixth Edition or recent edition, Macmillan Press .
2. Principles of Biochemistry, Voet, Voet and Pratt, 5th edition (2012) or recent edition, Wiley.
3. Harper's Illustrated Biochemistry, Murray, Granner and Rodwell, (27th Ed.), McGraw Hill, New York, USA.
4. Practical Biochemistry – Principles and Techniques, Wilson and Walker, Cambridge University Press, Cambridge [Latest edition].

**Course Learning Outcomes:**

It is expected that a student after taking up this course would acquire the knowledge and

understanding of evolutionary design of each metabolic pathways and its intermediates. The student would be able to predict the futuristic outcome of failure of metabolic pathways. Consequently, a scheme of intervention for metabolic failure through life style management can be predicted and which may also result into design of drugs.

## MS ZOOLC-105P: Core Practicals 1

1. Study of mutant phenotypes of *Drosophila*.
2. Demonstration of law of segregation and independent assortment using *Drosophila* mutants.
3. Demonstration of sex- linkage by using sex linked mutation in *Drosophila*.
4. Statistical analysis of genetic crosses.
5. Demonstration of dosage compensation by study of sex chromatin in human buccal smear and white apricot (*wa*) mutation in *Drosophila.*
6. Targeted tissue specific expression of genes using UAS-Gal4 System in *Drosophila*.
7. Preparation and study of metaphase chromosomes:

a. Chromosome banding (C, G, H banding).

8. Differences in number, shape and size of chromosomes in normal vs. tumor cells, or normal vs. irradiated cells (in human).
9. Preparation of human karyotype and study of chromosomal aberrations with respect to number, translocation, deletion etc. from the pictures provided.
10. Study of Orcein stained of mitotic chromosomes from *Drosophila* larval brain.
11. Study of transcriptional activity in polytene chromosome of *Drosophila* upon heat shock.
12. Plasmid DNA isolation: minipreps.
13. DNA quantification and purity of DNA.
14. Restriction enzyme digestion of plasmid DNA.
15. Purification of DNA from an agarose gel.
16. Vector and insert ligation.
17. Preparation of competent cells and storage.
18. Transformation of E. coli with standard plasmids, calculation of transformation efficiency.
19. Polymerase Chain Reaction, using standard 16S rRNAeubacterialprimers .
20. Observe and compare the inherent rhythmicity of the different parts of the heart.
21. Determine the effects of application of parasympathetic or sympathetic agonists/ antagonists.
22. Assessing physical and chemical modifiers of heart rate in frog.
23. Determine the response of the heart to direct electrical stimulation / vagal stimulation.
24. Effects of drugs and hormones on contraction of smooth muscles.
25. Demonstration of tetany, action current and fatigue in muscle.
26. Study the effect of load on muscle contraction.
27. Concentration / dispersal of pigment in isolated scales of dark / light adapted fish.
28. Examine the relative activity of enzymes in the fore, mid, and hindgut of a typical insect and correlate the enzyme activity with the different gut regions.
29. Determine the median threshold concentration of sucrose for housefly population.
30. Regeneration phenomenon in Planarian model.
31. Titration of an amino acid, an acidic dye and an organic acid to determine the pKa

value.

32. Preparation of a 'Good' buffer.
33. Preparation of molecular models using ball-and-stick
34. Sub- cellular fractionation of rat liver and marker enzyme assays.
35. Characterization of a purified protein/ enzyme for homogeneity molecular size by SDS-PAGE.
36. Verification of Beer's Law
37. Estimation of a sugar, an amino acid, a vitamin, a nucleotide/nucleic acid by appropriate chemical and biological methods.
38. Kinetic characterization of any one enzyme.
39. Determination of energy of activation for an enzyme mediated reaction.
40. In gel staining of an enzyme activity (Zymogram for any one enzyme).

## Semester –II
### Core Papers

### MS ZOOLC-201: Developmental Biology

**Course Objectives:**

The main objective of Developmental Biology course is to provide four-dimensional thinking of students to truly understand the patterns and process of embryonic development, body plan, fate map, induction, competence, regulative and mosaic development, molecular and genetic approach for the study of developing embryo which is not necessarily shared with any other disciplines in the biological sciences. The relevance of Developmental Biology to the study of human disease will be exemplified throughout using different model organisms.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Basic concepts of developmental biology**: cell division, cell differentiation, signaling, patterning; Evolution of developmental patterns. | 5 |
| **Unit 2.** | **Model systems:**vertebrates model organism- *Xenopuslaevis*, chicken, mammals, zebrafish; invertebrate model organism- *Drosophila melanogaster*, Sea urchin, *Caenorhabditiselegans.* | 5 |
| **Unit 3.** | **Early embryonic development of vertebrates and invertebrates:** structure of the gametes– the sperm, the egg; cleavage and gastrulation; axes and germ layers | 5 |
| **Unit 4.** | **Morphogenesis**: cell adhesion, cleavage and formation of blastula, gastrulation, neural tube formation, cell migration | 4 |
| **Unit 5.** | **Axis specification in *Drosophila***: role of maternal genes, patterning of early embryo by zygotic genes- gap genes, pair– rule genes, segment polarity genes, homeotic selector genes- bithorax and antennapedia complex. | 12 |
| **Unit 6.** | **General concepts of organogenesis:** Development and patterning of vertebrate limb, homeobox genes in patterning, signaling in patterning of the limb; Insect imaginal discs–organizing center in patterning of the leg and wing, the homeotic selector genes for segmental identity; insect compound eye | 8 |
| **Unit 7.** | **Postembryonic development:** growth, cell proliferation, growth hormones; aging- genes involved in alteration in timing of senescence | 5 |
| **Unit 8.** | **Regeneration**– Epimorphic regeneration of reptile (salamander) limb; Morphollaxis regeneration in hydra; embryonic stem cells and their applications | 5 |
| **Unit 9.** | **Medical implications of developmental biology**: genetic errors of human development- the nature of human syndromes– pleiotropy, genetic heterogeneity, phenotypic variability, mechanism of dominance; gene expression and human disease– inborn errors of | 8 |

nuclear RNA processing, inborn errors of translation; teratogenesis-environmental assaults on human development- teratogenic agents like alcohol, retinoic acid etc

**Unit 10.** **Programmed cell death:** apoptosis, autophagy and necrosis 3

**Suggested Literature:**

1. Developmental Biology: Scott F Gilbert [Latest edition].
2. Essentials of Developmental Biology: JMW Slack [Latest edition] .
3. Principles of Development: Louis Wolpert [Latest edition].

**Course Learning Outcomes:**

- Developmental Biology enquires about the fundamental processes that underpin the fertilization of an egg cell and its step-by-step transformation into the fascinating complexity of a whole organism.
- Students learn best by doing and by having the opportunity to put what they have learned into practice. Therefore, using various model organism as a learning tool in Developmental Biology, students will learn how a cell behaves in response to an autonomous determinant or an external signal depends on the combination of transcriptional and posttranscriptional regulators, signaling pathway components, cytoskeletal elements, and other proteins and RNAs that it has synthesized earlier: i.e., on its developmental history.
- Students will also understand that cells only express a proportion of their genome, and that differential gene expression underlies cell differentiation and any alteration in the entire process of development leads to devastating diseases.

## MS ZOOLC-202: Systematics, Biodiversity and Evolution

### Course Objectives:

The primary objective of the course is to impart appreciation for different life forms on earth and drive home the relationship between different living forms both at the genetic and the ecological level.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **An overview of evolutionary biology**: concept of organic evolution during pre- and post- Darwin era; evolution and molecular biology- a new synthesis; from molecules to life, life originated from RNA, introns as ancient component of genes. | 12 |
| **Unit 2.** | **The universal common ancestor and tree of life, three domain concept of living kingdom; molecular phylogeny:** history, terms, definition and limitations, construction of phylogenetic trees using molecular data, construction of phylogenetic trees by using 16S rRNA gene sequences and concept of speciation in bacteria; molecular divergence and molecular clocks and molecular drive; complication in inferring phylogenetic trees; origin and diversification of bacteria and archea; diversification of genomes; the nature of bacterial and archeal genomes; origin of genomes by horizontal gene transfer; role of plasmid, transposons, integrons and genomic islands in DNA transfer. | 18 |
| **Unit 3.** | **Origin and diversification of eukaryotes:** origin of cells and first organisms; early fossilized cells; evolution of eukaryotic cell from prokaryotes- a case of symbiosis; evolution of eukaryotic genomes; gene duplication and divergence. | 15 |
| **Unit 4.** | **Mode of speciation**: factors responsible for speciation; tempo of evolution; systematics- definition and role in biology, biological classification- theories and objectives, types of taxonomy, taxonomic diversity- definition and types, origination and extinction, rates of change in origination and extinction, causes of extinction, causes of differential rates of diversification, current status and future of biodiversity; human evolution- human evolutionary history; placing humans on tree of life; genomics and humanness; current issues in human evolution. | 15 |

### Suggested Literature:

1. Evolution, Barton, N. H., Briggs, D. E.G., Eisen, J. A., Goldstein, A. E., Patel, N. H., Cold Spring Harbor Laboratory Press, New York, USA
2. Evolution, Hall, B. K. and Hallgrimsson, B., Jones and Bartlett Publisher, Sudbury, USA
3. Evolution, Futuyma, D. J., Sinauer Associates, Inc., Sunderland, USA

4. What Evolution Is, Mayr, E., (2001), Basic Books, New York, USA

**Course Learning Outcomes:**

- Knowledge of evolution would facilitate in assessing the potential disease causing organisms and thus be able to design effective disease control strategies.
- The students would be able to suggest beneficial alterations in agricultural crops and livestock through variability studies.
- The students would be able to take up functional studies of many organisms.

## MS ZOOLC-203: Immunology

**Course Objectives:**

The primary objective of this course is to help students develop skills necessary for critical analysis of contemporary literature on topics related to health and disease and role of immune system. The course has been divided into two components: 1) lecture and discussion 2) practical demonstration.

The lecture-discussion part is conceptualized with the aim that students are taught the basics of immunology so as to develop understanding of the subject, such as howdoes the immune system works? What are the molecular and cellular components and pathways that protect an organism from infectious agents or cancer? This comprehensive course answers these questions as it explores the structure, function and genetics of the components of immune system. The course also emphasizes the research and development opportunities for therapeutic intervention arising from recent advances in immunology. The immunological aspects of disease will also be discussed using case-based studies. Upon completion of the course students have a sound understanding of the essential elements of the immune system, preparing them to engage further in this rapidly evolving field.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Overview of the immune system:** Components of the immune system, principles of innate and adaptive immunity, antigen and immunogenicity, clonal selection theory; Evolution of immune system. | 4 |
| **Unit 2.** | **Antigen recognition by immune cells**: Innate Immunity- Pattern recognition in the innate immune system, TLRs and their role in innate immune response; Adaptive immunity-Antibody structure, antigen recognition by B lymphocytes; molecular mechanism behind BCR formation; B lymphocyte development and survival. | 10 |
| **Unit 3.** | **Structure and function of MHC complex:** antigen processing cells, antigen processing and presentation to T lymphocytes, MHC restriction. | 8 |
| **Unit 4.** | **TCR structure and function:** T-cell receptor gene rearrangement; T lymphocyte development and survival; Antigen recognition by T-cells, signaling through TCR and T-cell activation, co- receptors and their role in T –cell functioning; co-stimulation. | 8 |
| **Unit 5.** | **Effector mechanisms and regulation of immune responses**: Induced innate response to infection, Innate memory, Complement system, NK and NKT cell functions, Humoral immune response, Production of effector T- cells, cytotoxic T- cell effector mechanisms. | 10 |
| **Unit 6.** | **Regulation of immune response:** Leukocyte activation and migration, Cytokines, innate regulation of the immune response, T-cell mediated | 10 |

| | | |
|---|---|---|
| | regulation of immune response, Immunological tolerance. Mucosal immunity. | |
| **Unit 7.** | **Immunity in health and disease:** Allergy and hypersensitivity, Autoimmunity, Immunodeficiency diseases, Immunity and Infection, Tumour-immunology, Transplantation, Vaccines. | 10 |
| **Unit 8.** | **Techniques related to immunology** | 4 |

**Suggested Literature:**

1. Kuby Immunology, Richard, Thomas, Barbara, Janis , W. H. Freeman and Company [Latest edition].
2. Immuno Biology- The immune system in health and disease, Janeway, Travers, Walport and Shlomchik, Garland Science Publishing [Latest edition].
3. Essentials of Immunology, David, Brostoff and Roitt, Mosby & Elsevier Publishing[Latest edition].
4. Fundamentals of Immunology by William E. Paul, Lippincott Williams & Wilkins Publishing [Latest edition].
5. Cellular and Molecular Immunology by Abul K. Abbas, Andrew H. Lichtman, Shiv Pillai, Elsevier Publishing [Latest edition].

**Course Learning Outcomes:**

At the end of the course, the students should be able to:

- The students will be able to identify the cellular and molecular basis of immune responsiveness and understand how the innate and adaptive immune responses coordinate to fight invading pathogens.
- Understand the immunomodulatory strategies essential for generating or suppressing immune responses as required in hypersensitivity reactions, transplantation, autoimmune diseases and cancer.
- Learn to review the literature to determine the strengths and weaknesses of the data published in immunology and its novelty.
- Design new methods to improve existing vaccines and other immunotherapeutic strategies.

## MS ZOOLC-204: Molecular Cell Biology

**Course Objectives:**

This course will provide knowledge about the complex organization in the eukaryotic cell and the molecular mechanisms of the cellular processes that exist in all cell types.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Cytoskeleton in eukaryotic cell architecture and function** - Recapitulation of the structure of the eukaryotic cell with emphasis on how it functions as a unit of life; Structure and dynamics of microfilaments; Organization of the cortical cytoskeleton; Actin cytoskeleton in cell shape, intracellular motility and cell locomotion; Microtubule structure, organization and dynamics; Role of microtubules in cell shape and mitosis;Structure and function of intermediate filaments. | 18 |
| **Unit 2.** | **Biology of Cell membranes** - Recapitulation of the plasma membrane;Mechanism of diffusion, facilitated diffusion, active transport with suitable examples; Movement of water;Ion movements and cell function: Acidification of cell organelles and stomach; transepithelial transport; Maintenance of cellular pH; Cell excitation; Bulk transport: Receptor mediated endocytosis;Protein sorting and targeting to organelles; Targeting of proteins to lysosomes for degradation; Molecular mechanism of the secretory pathway; Secretion of neurotransmitters. | 20 |
| **Unit 3.** | **Life cycle of a cell** - Cell cycle and its regulation; Commitment to cell division; Entry into and exit from the cell cycle; Checkpoints in the mammalian cell cycle;Turnover of cellular components; Degradation of cytosolic proteins; Mammalian cell culture and cytotoxicity. | 10 |
| **Unit 4.** | **Organization of cells into tissues and cellular communication** - Extracellular matrix; Cell- cell and cell-matrix adhesion; Cell junctions; Intercellular communication: Key concepts in cellular signaling mechanisms;Second messenger systems; G-protein coupled receptors; Receptor tyrosine kinases; MAP kinase cascade; Desensitization of receptors; Survival and death pathways. | 12 |

**Suggested Literature:**

1. Molecular Cell Biology, Lodishet al., W.H. Freeman and Company (8th Ed. 2016)
2. Molecular Biology of the Cell, Albertset al., W.W. Norton and Company (6th Ed. 2014)
3. Molecular Biology, Weaver R. F., McGraw-Hill Education (5th Ed. 2011)

**Course Learning Outcomes:**

The students will:

- Be able to understand how the cell functions as a unit of life.
- Gain knowledge about the techniques and experiments that contributed to the understanding of molecular mechanisms of the cellular processes.
- Be able to draw parallels between the physiological processes at the cellular and organismic levels.
- Appreciate the importance of cell-cell adhesion and the extracellular matrix in the evolution of multicellular organisms.

## MS ZOOLC-205P: Core Practicals 2

1. Study of life cycle and developmental stages of Drosophila melanogaster. Study of Homeotic gene mutations and its effect on patterning (Four winged fly).
2. Study of life cycle and developmental stages of Zebra fish.
3. Study of life cycle and developmental stages of C. elegans.
4. Study of effect of crowding on developmental delay of C. elegans (Dauer stage)
5. Study of tissue and developmental stage-specific expression of Drosophila developmental genes like engrailed, vestigial, wingless etc by UAS/GAL4 system.
6. A study of patterning of Drosophila adult wing and demonstration of the effect of cell death on the patterning of the adult wing.
7. Identification and study of larval and prepupal wing, leg and eye antennal imaginal discs of Drosophila.
8. A study of polarity and regeneration in Hydra.
9. Study of developmental stages of chick embryo.
10. Isolation of Genomic DNA from a bacterium and its quantification.
11. Designing primers for 16S rRNA gene sequence.
12. Amplification of 16S rRNA gene sequences by using genomic DNA as well as by colony boiling method.
13. Purification of 16S rRNA gene.
14. Sequence of 16S rRNA gene; editing the sequence, multiple alignments, construction of phylogenetic trees and interpretation of results.
15. Dot blot hybridization of different eubacterial species and interpretation of results.
16. Observation of primary and secondary immune organs from mice,
17. Preparation of single cell suspension from bone marrow and spleen (spleenocytes) of mice.
18. Cell counting and viability testing of the spleenocytes prepared.
19. Preparation and study of phagocytosis by spleenic/peritoneal macrophages and
20. Mactophage functional analysis by: a)Phagocytosis, b) Nitric oxide estimation.
21. Raising polyclonal antibody in mice, serum collection and estimation of antibody titre in serum by following methods: a)Ouchterlony (double diffusion) assay, b) ELISA
22. Antibody purification from the serum collected from immunized mice: a) affinity purification/chromatography, b) Immunoelectrophoresis.
23. Demonstration of Western blotting: a) Protein estimation by Lowry's method /Bradford's method, b) SDS-PAGE, c) Immunoblot analysis.
24. Protein estimation by Lowry method and interpolation of the unknown from the standard curve using the algebraic method.
25. Aseptic technique - Testing the efficiency of sanitization with 70% alcohol.
26. Sub cellular fractionation of functional mitochondria: a. Isolation of mitochondria from liver tissue by differential centrifugation. b. Determination of protein concentration in the fractions by Lowry method. c. Identification of mitochondrial fraction by assay of marker enzyme.
27. Mammalian cell culture.
28. Assessment of proliferation/ cytotoxicity in cultured cells by MTT assay.
29. Over-expression and affinity purification of SH3-GST recombinant protein from bacterial cells.
30. Demonstration of protein-protein interaction between recombinant SH3-GST fusion protein

and cellular proteins by SDS-PAGE

31. Effect of protein synthesis/ DNA synthesis inhibitor on cell responses to a hormone.
32. Electrophoretic mobility shift assay (EMSA) for Protein-DNA interactions.

## Semester –III

## Core Paper

## MS ZOOLC 301: Principles of Ecology

**Course Objectives:**

The objective of this course to make awareness among the young students about the surrounding environment, the impact of climate change and its mitigation, and biodiversity.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Concept of Ecology** - Introduction to ecology, evolutionary ecology, environmental concepts – laws and limiting factors, ecological models. Characteristics of population, population size and exponential growth, limits of population growth, population dynamics, life history pattern, fertility rate and age structure. Competition and coexistence, intra-specific and inter-specific interactions, scramble and contest competition model, mutualism and commensalism, prey-predator interactions. | 10 |
| **Unit 2.** | **Ecosystem -** Nature of ecosystem, production, food webs, energy flow through ecosystem, bio-geochemical cycles, resilience of ecosystem, ecosystem management. The biosphere, biomes and impact of climate on biomes. | 10 |
| **Unit 3.** | **Climate change** - Environmental Stresses and their management, global climatic pattern, global warming, atmospheric ozone, acid and nitrogen deposition, coping with climatic variations. | 10 |
| **Unit 4.** | **Bioremediation** - Major classes of contaminants. Uptake, biotransformation, detoxification, elimination and accumulation of toxicants. Factors influencing bioaccumulation from food and trophic transfer. Pesticides and other chemical in agriculture, industry and hygiene and their disposal. Impact of chemicals on biodiversity of microbes, animals and plants. Bioindicator and biomarkers of environmental health. Biodegradation and bioremediation of chemicals. | 15 |
| **Unit 5.** | **Biodiversity** – assessment, conservation and management, biodiversity act and related international conventions. Sustainable development, natural resource management in changing environment. Molecular ecology, genetic analysis of single and multiple population, phylogeography, molecular approach to behavioural ecology, conservation genetics. | 15 |

**Suggested Literature:**

1. Field Sampling: Principles and Practices in Environmental Analysis. 2004. Conklin, A.R. Jr. CRC Press.
2. Principles and Standards for Measuring Primary Production. 2007. Fahey, T.J. and Knapp, A.K. Oxford University Press, UK.
3. Ecological Modeling. 2008. Grant, W.E. and Swannack, T.M., Blackwell.
4. Fundamental Processes in Ecology: An Earth system Approach. 2007. Wilkinson, D.M. Oxford University Press, UK.
5. Principles of Terrestrial Ecosystem Ecology. 2011. Chaplin, F.S., Matson, P.A. and Vitousek, P.M. Springer.
6. Environmental Chemistry. 2010. Stanley and Manahan, E. CRC, Taylor & Francis. London.
7. Freshwater Ecology: A Scientific Introduction. 2004. Closs, G., Downes, B. and Boulton, A. Wiley-Blackwell publisher, Oxford.

## Practicals

**A. Habitat studies:**

1. Physical and chemical characteristics of soil.
2. Physico-chemical properties of water.

**B. Community/ecosystem studies:**

1. Assessment of density, frequency and abundance of plants/ animals in a community using various techniques i.e. transect, quadrate etc.
2. Decomposition of various organic matters and nutrient release mechanisms/role of arthropods and other micro- and macro-fauna in decomposition.
3. Understanding ecosystem succession by studying various stages of vegetation/community assemblages development.
4. Application of molecular techniques in ecological study.
5. Insect diversity in soil.
6. Identification of aquatic organisms of different trophic levels and construction of food chain and food web.

**C. Landscape studies:**

1. Principles of GIS, GPS and RS technology.
2. Interpretation (visual and automated) of remote sensing information for landscape differentiation.

**Course Learning Outcomes:**

- Students will be exposed to the fundamental aspects of ecology.
- They will get idea about the impact of anthropogenic activities on the environment.
- Students will get idea about the natural resources and their conservation.

## MS ZOOLC-302: Computational Biology, Biostatistics and Bioinformatics

### Course Objectives:

This course is meant to impart knowledge to students on the most import skill which is required in this era for any scientific worker. The course is designed in such a way that the students gets the confidence to use computer programs for the daily design of experiments, data collection, and analysis of results. The mandatory hand on practical exercises in the available state of art computer lab. in the Department will benefit students to learn all that they require to use their computer for the study of science.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **The era of computerized biology information**, review of relevant definitions in molecular biology, overview of challenges of molecular biology computingintroduction to phylogenetic analysis. Introduction to bioinformatics. Introduction to computational genomics and proteomics, Introduction to genomics and proteomics databases- nucleic acid sequence databases: Genbank, UCSC, ENSEMBL, EMBL, DDBJ, protein sequence databases: Swiss-prot, PDB, BLAST, PSI- BLAST (steps involved in use and interpretation of results) and HMMER, BLAST vs FASTA, file formats- FASTA, GCG and ClustalW. Databank search- data mining, data management and interpretation. Multiple sequence alignment of genes and primer designing. Phylogenetic analysis with the program PHYLIP, DISTANCES, and GROWTREE. Basics of designing a microarray, image analysis and normalization, annotations. | 15 |
| **Unit 2.** | **Basic components of computers–** hardware (CPU, input, output, storage devices), Software (operating systems), Application software; Introduction to MSEXCEL- use of worksheet to enter data, edit data, copy data, move data; Use of in- built statistical functions for computations of mean, S. D., correlation, regression coefficients etc., Use of bar diagram, histogram, scatter plots, etc., Graphical tools in EXCEL for presentation of data; Introduction to MS- WORD word processor- editing, copying, moving, formatting, table insertion, drawing flow charts, Introduction to Power Point, image and data handling and software like Endnote. | 10 |
| **Unit 3.** | **Biostatistics-** population, sample, variable, parameter, primary and secondary data, screening and representation of data, frequency distribution, tabulation, bar diagram, histograms, pie diagram, mean, median, mode, quartiles and percentiles, variance, standard deviation, coefficient of variation; Probability and distributions- definition of probability (frequency approach), independent events. Addition and multiplication rules, conditional probability, examples- bernoulli, binomial, poisson and normal distributions; bivariate data- scatter plot, correlation coefficient (r), properties (without proof), interpretation of r, linear regression: Fitting of lines of regression, regression coefficient, coefficient of determination; hypothesis, critical region, and error probabilities, tests for proportion, equality of proportions, equality of means of normal populations when variances known and when variances are unknown: chi-square test for independence, P- value of the statistic, confidence limits, introduction to one | 20 |

way and two- way analysis of variance.

| | | |
|---|---|---|
| **Unit 4.** | Proteins, secondary structure and folding, RNA secondary structures, protein prediction tools- protein secondary structure, molecular modelling, identification and characterization of protein mass fingerprint, world- wide biological databases.Protein modelling, protein structure analysis, docking, ligplot interactions. Introduction to the latest modern softwares and technologies. | 15 |

**Suggested Literature:**


1. Latest software and articles available on University internet sites and subscribed sites.
2. Latest e-books and the text books available in the Department and University Library.
3. Bioinformatics: Sequence and Genome Analysis, Mount, D. W. (2nd Ed., 2001), Cold Spring Harbor Laboratory Press, New York, USA.
4. Principles of Biostatistics, Pagano M., Gauvreau, K, (2000), Duxbury Press, USA.
5. Bioinformatics for Dummies, Claverie J. M., Notredame C., (2nd Ed., 2007), Wiley Publishing, Inc., New York, US.


## Practicals

1. Introduction to the statistical software like R and SPSS
2. Use of excel sheet and graph pad Prism for data processing.
3. Use of search engines like Pub-Med, Scopus, Science direct for reference material collection and management.
4. Nucleic acid and protein sequence databases.
5. Data mining for sequence analysis by use of Bioinformatics' tools.
6. Web– based tools for sequence searches and homology screening.
7. Primer designing for gene amplification and gene cloning.
8. Annotations: ORF finder, Use of ARTEMIS or any other suitable software.
9. Construction of phylogenetic trees for DNA and proteins.
10. Introduction to microarray technology.
11. Software to study protein structure.
12. Software to estimate the antigenicity of a protein/peptide.
13. Discuss the modern technologies for the subjects taught in theory and their use depending on their availability.
14. Identification of peptide finger print by nano LC- MS/MS and database search.

**Course Learning Outcomes:**

- Students studying this course will be able to perform the data analysis using the statistical tools available on any computer such as excel as well the programs for big and complex data. They will be able to handle high throughput proteomic and genetic data. They will be able to understand the maintenance of computers, server and big data files. This course will make them suitably knowledgeable to undertake the computer jobs in the offices in the hospitals, scientific academies, funding agencies in addition to the teaching institutions.

# Elective Courses for Semester III

**(Elective Courses – a student has to choose one course from the following two groups, and one open elective from other department)**

## Group-A

## MS ZOOLE- 303: Parasitology

### Course Objectives:

The course aims to give an overview of biological basis of parasitic lifestyles including host responses and parasite evasion of host defense mechanisms. The students are exposed to parasites that not only infect humans but also those of plants and animals. It emphasizes on the evolutionary aspect of host-pathogen interactions leading to host specificity. The students learn about transmission, epidemiology, diagnosis, clinical manifestations, pathology, treatment and control of major parasites. The course has been structured in a way that the students assimilate the classroom knowledge for applied aspects of parasitology and public health.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **General concepts:** Animal associations and evolution of host – parasite relationship, Immune response and self-defense mechanisms, immune evasion and biochemical adaptations of parasites, Zoonosis. | 5 |
| **Unit 2.** | **Blood parasites:** Malaria: Epidemiology, mode of infection, detection, immunity and immune evasion mechanisms: Coordinated switching for antigenic variation by malaria parasites, drug targets, mechanism of drug resistance, malaria vaccine strategies. | 8 |
| | **Leishmaniasis:** Sand fly biology in the life cycle of *Leishmania* parasites; critical role for sand fly midgutmicrobiota in *Leishmania* development and transmission, epidemiology, detection, protective and pathologic immune responses in leishmaniasis, immune evasion mechanisms, drug targets, mechanismof drug resistance, vaccine strategies. | 8 |
| | **Sleeping sickness**: Epidemiology, mode of infection, serum resistance in zoonotic trypanosomes, immunity and immune evasion mechanisms, dynamics of antigenic variation and VSG diversification, drug targets, mechanism of drug resistance, vaccine strategies. | 8 |
| **Unit 3.** | **Gastro-intestinal and other parasites:**Amoebiasis: Epidemiology, detection, immunity and immune evasion mechanisms, drug targets, mechanism of drug resistance, vaccine strategies. | 8 |
| | *Schistosoma*, *Wuchereria*, *Brugia*, *Ancylostoma*, *Trichinella* and *Dracanculus*: Epidemiology, mode of infection, detection, immunity and immune evasion mechanisms, drug targets, mechanism of drug resistance, vaccine strategies. | 11 |

| | | |
|---|---|---|
| **Unit 4.** | **Beyond humans:** Parasites of veterinary importance. Parasitic insects, mites and ticks; parasites of insects and their significance; nematode parasites of plants, morphology, biology, lifecycle and infection of crop plants by major plant parasitic nematodes, host parasite interactions. | 11 |

**Suggested Literature:**

1. Foundations of Parasitology, Roberts L.S. and Janovy J., McGraw-Hill Publishers, New York, USA.
2. Modern Parasitology: A Textbook of Parasitology, FEG Cox., Wiley-Blackwell, U. K.
3. Parasitology: A Conceptual Approach, Eric S. Loker, Bruce V. Hofkin

## MS ZOOLE 303:Biology of Parasitism [Practicals]

1. Study of prepared slides and museum specimens of selected parasites of representative groups of protozoans, helminths and arthropods.
2. Demonstration of *in vitro* culture of *Plasmodium*, infection of mice with *Plasmodium*, chasing the process of infection by histopathology and immune reactions.
3. Culturing insect parasitic nematode, and chasing the lifecycle of the nematode on the insect host.
4. Culturing an insect parasitoid and studying their infection on an insect host.
5. Studying the infection of tomato plant by root knot nematode.

**Course Learning Outcomes:**

Upon successful completion of this course the students would be able to:

- Understand the biology behind host-parasite interactions
- Learn about epidemiological concepts of parasitic infections of global importance
- Trained to diagnose, identify and detect some important parasites
- Learn pathological changes associated with parasite infections
- Discuss the role of vectors and intermediate hosts in parasite transmission
- Learn the role of vertebrate innate and adaptive immune system in controlling parasites
- Learn molecular biology concepts unique to parasite infections
- Define the biochemical targets of drugs targeting parasites
- Define the mechanisms of parasite drug resistance
- Define the immune evasion strategy employed by certain parasites

## MS ZOOLE-304: Chronobiology

### Course Objectives:

The course is open to students having Undergraduate degreee with Zoology as a subject and having background of Physiology or Neuroscience. The aim of this course is to enable students understand the importance of internal timing in regulation of daily and seasonal processes in organisms.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Chronobiology**: Introduction, History and Milestones, Clocks, Rhythm and Calendar, The biological timing system: Concepts and methods, Types: Ultradian, circadian and circannual rhythms. | 10 |
| **Unit 2.** | **Rhythm characteristics:** Free running rhythms, Entrainment and masking in the natural and artificial environment, *Zeitgebers:* Photic and non-photic, Parametric and non-parametric entrainment, Phase shift, Phase response curves (PRC) and phase transition curves (PTC). | 12 |
| **Unit 3.** | **Circannual rhythms:** Proximate and Ultimate factors, Circannual control of seasonal processes, Photoperiodism: Concepts and photoperiodic time measurement models, Seasonal processes and photoperiodic control mechanisms. | 12 |
| **Unit 4.** | **Organization of circadian system in multicellular organisms:** Concept of central and peripheral clock system, Retinal and pineal clocks, Melatonin: Input to or output of the clock system, Anatomy of the circadian clock: Clock in the suprachiasmatic nucleus (SCN) as the example. | 10 |
| **Unit 5.** | **Generation of circadian timing:** Molecular feedback loops, Transcription, translation and posttranslational mechanisms, Circadian timing in diverse organisms (Drosophila, zebrafish, birds and mammals). | 8 |
| **Unit 6.** | **Human temporal structure:** Biological clocks and human health and diseases, Clock dysfunction and lifestyle related disorders, Chronopharmacology, chronomedicine, chronotherapy. | 8 |

### Suggested Literature:


1. Insect Clocks (3rd edition): D.S. Saunders, C.G.H. Steel, X. Afopoulou (ed.) R.D. Lewis. 2002 Barens and Noble Inc. New York, USA
2. Chronobiology Biological Timekeeping: Jay. C. Dunlap, Jennifer. J. Loros, Patricia J. DeCoursey (ed). 2004, Sinauer Associates, Inc. Publishers, Sunderland, MA, USA
3. Circadian Medicine: Christopher Colwell (ed.) Wiley-Blackwell (2015)
4. Circadian Physiology: Roberto Refinetti, CRC Press (3rd ed) 2016
5. Biological Timekeeping: Clock, Rhythms and Behaviour, Vinod Kumar (ed. 2017)

Springer India Pvt Limited.

## MS ZOOLE 304:Chronobiology [Practicals]

1. Assay of circadian rhythms using animal model systems.
2. Assay of circadian activity rhythms in human.
3. Ambulatory blood pressure monitoring and circadian analysis.
4. Quantifying oscillations: phase, period and amplitude.
5. Dry lab exercises on the previously recorded data.
6. Recording of body temperature (Tb) of human.
7. Experiments demonstrating the photoperiodic clock.

### Course Learning Outcomes:

At the end of the course, the students should be able to

- Conceptualize how species profitably inhabit in the temporal environment and space out their activities at different times of the day and seasons.
- Understand the molecular, cellular and system levels the generation and coordination of internal timing.
- Develop a critical viewpoint and to interpret observations from experiments on biological rhythms regulating daily and seasonal biology.
- Plan studies on biological rhythms in both human and non-human species.
- Understand the consequence of the disruption of internal rhythms on work performance and health in the modern world.

## MS ZOOLE-305: PROTEIN STRUCTURE, FUNCTION AND EVOLUTION

**Course Objectives:**

Protein is associated with both structure and cellular functions. The course will help in understanding mechanism by which proteins give shape to cells and how pathways are regulated.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Chemical Nature of polypeptide**: Various types of amino acids and their side chains, nature of amino acids, L and D amino acids in nature and their importance, non-ribosomal peptides, Extracellular matrix and proteoglycans, Glycoproteins and their role in cellular processes, Super molecular assembly involving proteins, nucleic acid and lipids using examples of multi-enzyme complex, chromatin and chylomicrons. | 15 |
| **Unit 2.** | **Structure of Protein:** Functional and Structural Proteins, Regular conformations of polypeptides: α-helices and β-sheets, Secondary, tertiary and quaternary structure of proteins, Forces which decide protein structure, Ramachandran Plot, Structural motif and functional domains, Protein folding, Protein Families, Protein data bases, convergent and divergent evolution of protein structure and functions; protein engineering. | 15 |
| **Unit 3.** | **Overview of Protein biosynthesis, and the Cellular signal transduction**: Membrane and intracellular receptors, Receptor-ligand interaction, Protein mediated signaling in mammalian and bacterial system (G-proteins, Tyrosine kinase, Serine/threonine kinase, histidine/aspartate kinases, arginine kinase). Role of ten major modifications in protein structure and function. Small G-proteins in cell signaling. | 15 |
| **Unit 4.** | **Protein half life and Protein Degradation**, Protein as source of Energy, Protein denaturation, genetic disorder affecting functional proteins, Diseases by protein aggregation and Prion, Protein Separation techniques. Techniques for protein identification. | 15 |

**Suggested Literature:**

1. Proteins-Structure and Molecular Properties, Creighton T.E., Freeman Company New York, USA
2. Introduction to protein structure, Braden and Tooze, Garland Publishing, London, U K
3. Biochemistry, Voet D., AND J. G. Voet, Jon Wiley and Sons Inc., USA

## MS ZOOLE 305: Proteins-Structure, Functions and Evolution [Practicals]

1. To study the effect of overexpression of recombinant protein on growth of E.coli.
2. Overexpression of recombinant protein and separation on SDS-PAGE
3. Identification of overexpressed recombinant protein by Western blotting
4. Purification of overexpressed protein by Affinity Chromatography
5. Quantification of purified protein by Bicinchoninic Acid Assay(BCA) and UV absorption.
6. Post translational modification of protein and its detection by Western Blotting.
7. Ligand binding to protein and determination of Kd value.
8. Estimation of tryptophan and cysteine content by spectrophotometry.
9. Microheterogeneity in proteins-separation of charge isoforms by ion-exchange chromatography.
10. Quantitative precipitin test and estimation of number of antigenic epitopes.

**Course Learning Outcomes:**

- Student will understand how proteins give shape and structure, how protein quality is maintained in the cells so that all pathways can run to their optimum level. They will also know how mutations in proteins can lead to diseases.

## Group B

## MS ZOOLE- 306: Structure and Function of Genes

**Course Objectives:**

The course aims to bring a direct linkage between chemical structure of nucleic acids and their known functions. It is often elusive in the minds of students that why and how the specialized roles for the two nucleic acids (DNA & RNA) would have evolved, and the course aims to discuss the possible mechanisms for the functions of these two informational macromolecules. Biological properties and emergent in nature, and in the terms of gene regulation, it is defined as emergent behavior of cis-acting elements (a DNA or RNA sequence) with a trans-acting factor (a diffusible molecule that could be a protein or RNA). Therefore, it is also planned to cover the design of a transcription unit that is often used to annotate a gene from genomics data. The problems of accuracy during information-transfer (replication, transcription and translation) and the mechanism to solve the transmission of misinformation will also be discussed.

The course is designed as an elective course for a student who has interest to study genes, genomics and epigenetics at advance level and has already studied the basic genetics and biochemistry of macromolecules.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **The genetic material and its evolution** - Structure of nucleic acids - folding motifs, conformation flexibilities, super-coiling of DNA; Packaging of DNA in the nucleus- structure of chromatin, chromatin territories; Structure and function relationships in the genetic material; Evolution of genetic material; Energetics of nucleic acid polymerization; Accuracy during flow of genetic information; DNA polymerases. | 15 |
| **Unit 2.** | **Flow of genetic information** - Comparison of prokaryotic and eukaryotic DNA replication initiation; Termination of replication; Proof- reading activity; Transcriptional control of gene expression- positive and negative regulations, RNA polymerases, promoters and regulatory sequences, activators and repressors of transcription, transcription initiation by RNA polymerases, regulation of transcription-factor activity, elongation and termination of transcription. | 12 |
| **Unit 3** | **Stability and variation in the genetic material** - Errors and damage in the DNA; Mechanism of DNA repair; Genome instability; Homologous and site-specific recombination - Models of homologous recombination; Mechanism of homologous recombination in prokaryotes and eukaryotes; Site-specific recombination. | 8 |
| **Unit 4.** | **Post-transcriptional gene control and nuclear transport** - Processing of the 5' and 3' ends of eukaryotic mRNA; Types of introns and their splicing, Evolution of introns; Catalytic RNA; Alternative splicing and | 15 |

proteome diversity; Regulation of alternative splicing; Trans splicing; Processing of rRNA and tRNA precursors; Micro RNA and other non-coding RNAs; Transport across the nuclear envelope- Structure of the nuclear membrane and the nuclear pore complexes; Processes of nuclear import and export and their regulation.

**Unit 5.** **Fate of RNAs exported from the nucleus**- Stability of RNA; Degradation of RNA. Translational machinery and translational control- Energetics of amino acid polymerization, tRNAs and their modifications; Amino-acylt-RNAsynthetases; Accuracy during amino-acylation of tRNA; Initiation of translation in prokaryotes and eukaryotes and its regulation; elongation and its control, Termination of translation. 10

**Suggested Literature:**

1. Molecular Biology of the Gene, Watson *et al*. (7th Ed. 2017), Pearson Education, Delhi, INDIA
2. Lewin's Genes XI (2014), Jones and Bartlett Publishers, Boston, USA
3. Molecular Cell Biology, Lodishet al., W.H. Freeman and Company (8th Ed. 2016)
4. Accuracy in Molecular Processes: Its Control and Relevance to Living System, TBL Kirkwood, RF Rosenberger, and DJ Gala (1989), Chapman and Hall, NY, USA.

## MS ZOOLE 306: Structure and Function of Genes [Practicals]

1. Familiarization with sterile-handling techniques for culture of bacteria.
2. Study of growth of *E. coli* in Lysogeny broth batch culture and determination of generation time and log-phase from the growth curves.
3. Study of growth of *E. coli* in M9 minimal medium batch culture for determination of log-phase for metabolic experiments.
4. Induction of the *lac* operon in *E. coli* with lactose
5. Catabolite repression of *lac*-operon and role of cAMP.
5. Isolation of genomic DNA from mouse/rat liver or cell line.
6. Measurement of absorption-spectrum of DNA, RNA, and nucleotides.
7. Study on stability of DNA and RNA towards alkali.
8. Assay of DNA damage by Comet assay.

**Course Learning Outcomes:**

- It is expected that a student after completing this course would have fairly good understanding of evolution of genetic material and the design of functional modules (Unit) in the whole genome settings. The student would be able to structurally and functionally annotate a gene from the genomic database. Also, they should be able to design experiments for understanding the advanced functional genomics.

## MS ZOOLE-307: Animal Behaviour

**Course Objectives:**

Behavior is one of the most important and interesting aspects of animal biology. Behaviors permit flexibility that allows animals to respond rapidly to environmental changes. This course exposes students to the broad field of animal behavior. Students will come to understand the historical foundations of the field, as well as current theories and evidence for a broad range of behavioral topics. We will also focus on how the science underlying our theoretical understanding of behavior is conducted, and how behavioral hypotheses at all levels of analysis can be tested experimentally. Students also participate in practical exercises to learn some fundamental techniques used to study behavior, and will practice reading and analyzing current scientific literature. Behavioral ecology and the evolution of behaviors as adaptations will be recurring themes interwoven through all topics discussed. The purpose of the Animal Behavior Laboratory is for students to have hands-on experiences designing and implementing experiments that concern a variety of behavior

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **An evolutionary approach to Animal behavior:** History of the study of animal behavior, objectives of behaviour, mechanism of behavior: Neural control of behavior, sensory processes and perception, ecology of senses. | 10 |
| **Unit 2.** | **Complex behavior**: Instinct and learning, Innate releasing mechanisms: key stimuli, stimulus filtering, supernormal stimuli, open and closed IRM. Fixed action pattern- characteristics and evolutionary features. Mimicry, mimetic releaser and code breakers. | 10 |
| **Unit 3.** | **Mechanism of orientation:** primary and secondary orientation; kinesis and taxis. Learning and cognition: habituation, classical conditioning, operant conditioning, latent learning, social learning, Homeostasis and behaviour: motivational system and their physiological basis, motivational conflict and decision making, displacement activity, Hormonal regulation of behaviours. | 10 |
| **Unit 4.** | **Parental care and mating systems:** parental manipulation, evolutionarily stable strategy, cost benefit analysis of parental care. Sexual selection: intra sexual selection (male rivalry), inter-sexual selection (female choice), infanticide, sperm competition, mate guarding, consequences of mate choice for female fitness, monogamous verses polygamous sexual conflict. | 15 |
| **Unit 5.** | **Altruism:** reciprocal altruism, group selection, kin selection and inclusive fitness. An over view of Sociality in animal systems. Social organization in honey bees. Cooperation and conflict in animals. | 5 |
| **Unit 6.** | **Human behavior:** An introduction to human behavior, human non-verbal communication, mate selection and sexual strategy, family relationships and altruism, Linkingbehaviours to the brain, genes, hormones and environment. | 10 |

**Suggested Literature:**

1. An Introduction to Animal Behaviour (6th Edition). Aubrey Manning and Marian Stamp Dawkins, Cambridge University Press.
2. Animal Behaviour: An Evolutionary Approach, 9th Edition. John Alcock, Sinauer Associate Inc., USA, 2009.
3. Animal Behaviour (11th Edition). Dustin R. Rubenstein and John Alcock, Sinauer Associate Inc., USA, 2018.
4. Neuroscience of Emotion: A New Synthesis. Ralph Adolphs and David J. Anderson, Princeton University Press, 2018.
5. The Honey Bee. James L. Gould and Carol Grant Gould, Times Books, 2002.
6. The Wisdom of the Hive. Thomas D. Seeley, Harvard University Press, 1995
7. Honeybee Democracy. Thomas D. Seeley, Princeton University Press, 2010.
8. The Selfish Gene. Richard Dawkins, Oxford University Press, 2016.

## MS ZOOLE 307: Animal Behavior [Practicals]

1. To study the geotaxis, phototaxis, chemotaxis and hydrotaxi of earthworm.
2. To study the response of woodlice to hygrostimuli.
3. Fixed action pattern in spider.
4. Habituation in snail.
5. Behaviour observations in a primitive eusocial wasp.
6. Courtship and mating behaviour in *Drosophila.*
7. Foraging behaviour in a (Myna bird).
8. Behavioural profiling of a primate *Macacamuletta.*
9. Territorial behaviour in stray dogs.

**Course Learning Outcomes:**

At the completion of their Animal Behavior course, students will be able to:

- Exhibit critical and integrative thinking skills
- Demonstrate ability to communicate scientific information in both oral and written formats
- Demonstrate knowledge of key concepts in animal behavior
- Exhibit quantitative research skills (or demonstrate ability to perform all parts of the scientific method)
- Demonstrate ability to think flexibly and apply knowledge to new problem

## MS ZOOLE-308: Comparative Endocrine Physiology

**Course Objectives:** The course is designed to develop deep understanding on evolution of endocrine physiology.

**Course content:**

### Theory

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Concept of Endocrinology:** Introduction to the endocrine system, Classes of hormones, Modes of hormone secretion. | 2 |
| **Unit 2.** | **Evolution of endocrine system and its physiology: In Nemerteans**, In Annelids: Neurohemal organ and its function, In Mollusks: Neurohemal organ and its function, Endocrine physiology of Arthropods. **In Insects:** Types of hormones and their release sites, Prothoracicotropic hormone, Ecdysteroids, Juvenile hormone, Neuropeptides, Vertebrate-type hormones **In Crustaceans:** X-organ, Y-organ and associated neurohemal organs. Endocrine physiology of Echinodermata: Neuropeptides and reproduction. | 8 |
| **Unit 3.** | **Endocrine control of various physiological mechanisms**: moulting, diapause, growth and metamorphosis, osmoregulation, myotropic and metabolic factors, colour changes and reproduction. Hormone mimics and their applied value. | 10 |
| **Unit 4.** | **Comparative aspects of endocrine physiology in vertebrates:** Evolution of pituitary gland, Physiological actions of pituitary hormones-Adenohypophysial hormones: Somatotropin and prolactin, Glycoprotein hormones (FSH, LH, and TSH), Pro-opiomelanocortin, Neurohypophysial hormones: Oxytocin and vasopressin, Urophysis (fishes): Urotensin | 10 |
| **Unit 5.** | **Evolution of discrete adrenal gland:** Synthesis of corticosteroid, Structural diversity of glucocorticoids among vertebrates, Role of glucocorticoid in gluconeogenesis, Evolution of renin-angiotensin system, Hormonal control of water and electrolyte balance, Catecholamine biosynthesis, its storage and release mechanism, Importance of adrenocortical and adrenomedullary interaction, Physiological actions of adrenal medullary hormones. | 10 |
| **Unit 6.** | **Evolution of thyroid gland,** Thyroid hormone synthesis and its regulation.Paradigms of thyroid hormone action in poikilotherms and homeotherms; A comparative account of parathyroid gland and ultimobranchial body/C cells.Synthesis of parathyroid hormone, calcitonin and vitamin D3. Benthic organisms and source of vitamin D. Hormonal regulation of calcium and phosphate homeostasis, Hormonal regulation of calcium and phosphate homeostasis. | 10 |
| **Unit 7.** | Hormonal control of feeding behaviour and gastrointestinal tract functioning including acid release, gall bladder contraction and relaxation, pancreatic enzyme secretion, and GI tract motility. Pancreatic hormones and glucose homeostasis. | 4 |

**Unit 8.** Hormones, vitellogenesis, and the evolution of viviparity. 4
Environmental pollutants and endocrine physiology.

**Suggested Literature:**


1. Review articles published in various journals: "Endocrine Reviews/General and Comparative Endocrinology/Journal of Endocrinology/ International Review of Cytology/Molecular and cellular endocrinology/The journal of Clinical Endocrinology and Metabolism/Indian Journal Endocrinology and Metabolism.
2. Endocrinolgy by L.J. DeGroot, 5th ed., 2006 (Recent edition if published).
3. Vertebrate Endocrinology by David O. Norris Elsevier Academic press, 2007 ( recent edition if published).
4. Hand Book of Physiology published by American physiological Society by Oxford University Press, Section 7: Multiple volumes set, 1998.
5. Comparative Vertebrate Endocrinology by P.J. Bentley, Cambridge University Press, 1998.
6. The Insects: Structure and Function by R. F. Chapman, Published by The English Language Book Society(ELBS) and The English Universities Press Ltd.
7. The Principles of Insect Physiology by V.B. Wigglesworth. Published by ELBS and Chapman and Hall


## MS ZOOLE-308: Comparative Endocrine Physiology [Practicals]

1. Demonstration of retro-cerebral complex (endocrine system) in insects (e.g., cockroach/any other insect).
2. Effect of hormone mimic on the metamorphosis and other bio-characteristics of lepidopteran insect (e.g., Spodopteralitura).
3. Demonstration ofneurohaemal organ in a crustacean.
4. Demonstration of central nervous system in annelids ( brain/CNSin earthworm) and mollusks (Brain/Optic glands in octopus).
5. Pituitary cytology: a comparative study following histology, histochemistry and immunocytochemistry.
6. Role of glucocorticoid in carbohydrate, lipid and protein metabolism following adrenalectomy and glucocorticoid replacement therapy in rat.
7. Experiment to demonstrate the control of zona glomerulosa of adrenal cortex: effect of metyrapone and saline administration on adrenal cortex following light microscopy.
8. Role of thyroid hormone in oxygen consumption and reproduction in rat/wall lizard following thyroidectomy and thyroid hormone replacement therapy.
9. Steroid and thyroid hormone assay by ELISA.
10. Calcium estimation following fluorometry in PTH/Calcitriol treated rats.
11. Effect of orexigenic and anorexigenic hormones on feeding behaviour of rats.
12. Induction of vitellogenesis in a seasonally breeding non-mammalian vertebrate.

**Course Learning Outcomes:**

This course will help in advancing our knowledge on endocrine pathology employing molecular tools and techniques. Further, Comparative Endocrine Physiology course will equip the students to know how residue of pharmaceuticals, estrogenic compounds coming from indiscriminate use of polythene and other pollutants present in aquatic/terrestrial system are severely affecting the hormone secretion and thereby , terrestrial and aquatic biomes.

## Semester –III Open Elective

## MS ZOOLOE-309: Behavior of Social Animals

**Course Objectives:**

This paper is designed to be taken up by students from diverse interdisciplinary backgrounds, such as Anthropology, Environmental Studies, Biomedical Sciences, Physics, Psychology, Sociology and Economics etc.

Social behavior consists of a set of interactions among intraspecific individuals. A wide range of sociality occurs among animals. Some animals rarely if ever interact with one another, even when it comes to issues of parental care. Examples of relatively asocial animals include mosquitoes and polar bears. Highly social organisms live together in large groups, and often cooperate to conduct many tasks. Examples of social groups include packs of wolves and schools of fish. The most highly social animals form tightly regulated colonies and include all ants and termites, some bees and wasps, and a few other organisms.As humans, we are highly social animals. Our daily lives often include interactions with other members of our species, collectively called **social behaviors**.

Social and altruistic behaviors require a broad view of Darwinian fitness and an understanding that animals can perform behaviors that are responsive to short-term and long-term consequences for their fitness. By understanding how organisms interact with their environment and how the environment is predictive of their survival and reproductive success, it would be feasible to explain how social behavior has evolved via the mechanism of natural selection.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Adaptive nature of Social Behavior,**<br>**Altruism**: One animal in the group may do something to increase the survival of another at the potential cost to its own fitness or survival. This behavior is known as **altruism**<br>**Reciprocity:** Vampire bats returning from an unsuccessful foraging bout will beg to share food from successful individuals. It is most directly in the interest of the solicited bat to keep its own food, as it requires the nutrients to survive and reproduce, and giving up part of its meal is in fact altruistic. Thus in both ecological and evolutionary terms, other members of this bat's own species are its greatest competitors. | 6 |
| **Unit 2.** | **Kin Selection:** When an altruistic act is performed for a member of one's own family it is called kin selection. This increases the reproductive fitness (survival) of future generations.<br>**Eusociality:**The evolution of social behavior at its most intimate and complex degree is found in eusocial animals. Eusocial species live in colonies. Only a relatively small fraction of the animals in the colony | 6 |

| | | |
|---|---|---|
| | reproduce; the non-reproductive colony members provide resources, defense, and collective care of the young. The list of known eusocial animals includes ants, termites, some wasps, some bees, a small number of aphid and thrip species, two species of mammal (the naked mole rat and the Damaraland mole rat), and multiple species of reef-dwelling shrimp. | |
| **Unit 3.** | **The Social Brain: Neural Basis of Social Knowledge:** Social cognition in humans is distinguished by psychological processes that allow us tomake inferences about what is going on inside other people—their intentions, feelings, and thoughts. These distinctive states are reflected in the neural structures that underlie social cognition. | 6 |
| **Unit 4.** | **Dominance and Hierarchy:**Many social groups are organized, by social ranking. Many primate, canine and other social groups are organized through a dominance hierarchy. The male or female in charge is the most dominant, the alpha, the leader of the group, While many groups are male dominant, some groups, like the spotted hyena and bonobo, are female dominant. | 6 |
| **Unit 5.** | **Agonistic Behavior:**A confrontation between individuals in a social group may involve a number of agonistic behaviors. These behaviors are used to display one's fitness to a challenger in an attempt to intimidate him or her into backing down, like ritualistic fighting displays. E.g., a dog growling and bearing its teeth, or an elephant stomping its feet and flapping its ears. | 6 |
| **Unit 6.** | **Social brain hypothesis and its implications for social evolution:** As per the hypothesis, the cognitive demands of sociality have driven the evolution of substantially enlarged brains in primates and some other mammals. | 6 |
| **Unit 7.** | **Evolutionary relationships between sociality, cognition, and brain size in insects**:Insects are characterized by an extreme sophistication of social behaviors and relatively simple nervous systems. Major behavioral innovations of social insects may in fact require little information-processing and minor adjustments of neural circuitry, thus potentially selecting for more specialized rather than bigger brains. | 6 |
| **Unit 8.** | **Social brains: Do insect societies share brain power?**As social behavior evolved, the brain regions for central cognitive processing in social insect species may have gotten smaller -- the exactly opposite of the pattern that has been documented for several kinds of vertebrate animals including mammals, birds and fish. In *Mischocyttarus* wasps exhibiting relatively simple societies, never reach large colony sizes. These wasps are thought to represent a fairly early stage in social | 6 |

evolution, possibly like species at the transition from solitary to social living.Shaping of animal behavior, cognition, and brains by the environment (including social interactions): Brain functions, identify neural circuitry correlates of social tasks. Community "Brains": Stony corals of the family Scleractinia are very simple animals that have no central nervous systems. Nevertheless, they form extensive colonies in which individual members share resources. Some specialize in reproduction, others in defense, and still others in building the physical structure of the colony. Corals also "warn" each other of predators and coordinate various activities such as pulsing together to remove sediment from the colony.

**Unit 9.** **Information processing in miniature brains:** Since a comprehensive understanding of brain function and evolution in vertebrates is often staggered by the sheer size of the nervous system, as well as ethical concerns, major research efforts have been made to understand the neural circuitry underpinning behaviour and cognition in invertebrates, and its costs and benefits under natural conditions. Neural underpinnings and adaptive benefits (and costs) are described in a range of animals from marine invertebrates with exquisitely simple nervous systems to social insects forming societies with many thousands of individualsworking together as a'superorganism'. There is an urgent need to understand the full neuron-to-neuron circuitry underlying various forms of information processing-not just to explore brain function comprehensively, but also to understand how (and how easily) cognitive capacities might evolve in the face of pertinent selection pressures. In the invertebrates, reaching these goals is becoming increasingly realistic. 6

**Unit 10.** **Epigenetic mechanisms in the development of behavior:** The changes in the activity of genes established through epigenetic alterations occur as a consequence of exposure to environmental adversity, social stress, and traumatic experiences. DNA methylation in particular has thus emerged as a leading candidate biological pathway linking gene-environment interactions to long-term and even multi-generational trajectories in behavioral development, including the vulnerability and resilience to psychopathology. 6

**Suggested Literature:**

1. Social Behaviour in Animals,Tinbergen, J., Chapman & Hall, India[ Latest edition].
2. Animal Behavior, Michael Breed & Janice Moore, Elsevier Inc. [ Latest edition].

**Course Learning Outcomes:**

- After going through this common elective course, the students will understand and appreciate the diverse behaviours of the social animals (including invertebrates, vertebrates and mammals).
- The students will understand the dynamics and evolution of social behavior of differently evolved animals, by studying the various interactions and their neural basis of a variety of social animals.
- The students may appreciate social behavior from its neurological underpinnings to the survival and propagation strategy.

## Semester IV

**(Elective Courses – a student has to choose one of the following four streams, and each stream has four papers)**

## Stream – 1Entomology

## MS ZOOL-4101E Insect Diversity, Society and Evolution

### Course Objectives:

Insect diversity society and evolution attempts to introduce students to the various orders and some of the most important families of insects so that they can distinguish between harmful and beneficial insects, which form the basis of entomology. The course emphasizes on understanding the morphological fundamentals of insects in order to understand their diversity. This is followed by understanding the unique morphological characters of the insects belonging to each of the 29 insect orders and also their biology, natural history and succinct features. Students would also be introduced to the classification and evolution of these 29 orders. Understanding insect societies would empower the student to appreciate their societal implications. Besides many social insects are good candidate biocontrol agents.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Introduction to insects and their biology:** Morphology: external features and their articulation. | 13 |
| **Unit 2** | Comparative study of head-antennae, mouth parts; thorax – legs, wings; abdominal appendages, genitalia of the different orders of insects | 23 |
| **Unit 3.** | **Historical development of classification of insect**: basis of insect classification; classification of insects up to sub orders and up to super families in economically important groups; fossil history, origin and evolution of insects. | 4 |
| **Unit 4.** | **Insect Society:** group of social insects and their social life.Evolution of sociality;Social organization and social behaviour in honey bee, ants, termites, aphids and wasps | 20 |

### Suggested Literature:

1. A general text book of entomology, Imms , A. D., Chapman & Hall, UK
2. Introduction to the study of insects, Borror, D. J., Triplehorn, C. A., and Johnson, N. F.,M Saunders College Publication, USA
3. Principles of Insect Morphology, Snodgrass, R. E., Cornell Univ. Press, USA
4. The Insect Societies, Wilson, E. O., Harvard Univ. Press, UK .
5. Whitfield, J. B. and A. H. Purcell III. 2014. *Daly and Doyen's Introduction to*

*Insect Biology and Diversity. 3rd Edition.* Oxford University Press, Oxford, UK. 718 pp

**Course Learning Outcomes:**

- Following completion of this course, they would acknowledge the value and importance of insects and the students would be able to sight identify most of the 29 orders of insects. They will also know the basic biology and the significant identification characters of the insects belonging to each of the 29 orders. They would also learn the latest ideas of comparing these insects in an evolutionary perspective. Studying insect societies, students would develop an ability to appreciate their implications on societal impacts. They would also be able to identify and use various insects as biocontrol agents.

## MS ZOOLE-4102: Insect Physiology

### Course Objectives:

Insect Physiology is the study of the properties, processes, and functions of insect systems. As a component of this course we study some major biochemical molecules and their physiological actions to examine and understand the structure–function correlates within the various physiological systems functioning in insects.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Integumentary system:** Structure, function & formation, Growth, Moulting and Metamorphic development, hormonal influence, Sclerotization. | 4 |
| **Unit 2.** | **Endocrine system:** Insect hormones- with reference to metamorphosis & reproduction. | 10 |
| **Unit 3.** | **Digestive & Excretory system:** Alimentary tract, digestive and excretory physiology, Malpighian tubules, osmoregulation. | 10 |
| **Unit 4.** | **Circulatory system:** Open circulatory system, hemolymph, hemocytes, Immunity and thermoregulation. | 8 |
| **Unit 5.** | **Respiratory system:** Tracheal system and physiology of gas exchange. | 8 |
| **Unit 6.** | **Reproductive system:** Female & Male reproductive systems; Usual and unusual modes of reproduction. | 8 |
| **Unit 7.** | **Nervous system:** Components of the nervous system, Sensing the environment - Sensory receptors, vision & acoustics. | 8 |

### Suggested Literature:

1. The Principles of Insect Physiology, Wigglesworth, Vincent B, Chapman & Hall Ltd. USA.
2. The Insects: Structure and function, Chapman, R. F., Cambridge University Press, UK
3. Physiological system in Insects, Klowden, M. J., Academic Press, USA
4. The Insects, An outline of Entomology, Gullan, P. J., and Cranston, P. S., Wiley Blackwell, UK
5. Insect Physiology and Biochemistry, Nation, J. L., CRC Press, USA

### Course Learning Outcomes:

A student in this course should be able to:

- Become familiar with the various physiological systems operating in insects
- Identify the influence/control (neural and/or hormonal) within each system.
- Develop a sense of how physiology can be infused in major research topics in entomology.
- Understand the feasibility of using insects, as a eukaryotic model, for translational research in higher vertebrates (especially human beings)

## MS ZOOLE- 4103: Insect Toxicology and Ecology

### Course Objectives:

This course includes the study of Pesticides that are agrochemicals and used for preventing, repelling, mitigating or destroying any pests. It includes insecticides, fungicides, rodenticides and herbicides etc. These insecticides are of chemical or biological origin that control the insect. The course indicates the mechanism of Pest control that may result in the form of killing the insects or otherwise preventing it from its destructive behaviors. Insecticides are either natural or man-made synthesized and are applied to target pests in a myriad of formulations (EC,WP, SP, FP, G etc.) and delivery systems (sprays, baits, slow-release diffusion, dust, etc.). In recent years, the bacterial genes coding for insecticidal proteins have been incorporated into various crops that deal with the mortality of the pests feeding on them.

The course highlights various categories of insecticides and their relative efficacy in relation to other control methods in a particular ecosystem. Use of bio-pesticides and other plant derived pesticides form an important part of IPM (Integrated Pest Management)

The course indicates the **biodiversity of insects in different ecosystems and the im**pact of global climatic changes on insects diversity and their behaviour. Insects are important for the survival of different biota on the earth. Effect of various anthropogenic activities and pollutants on insects is correlated with maintenance of different ecosystems.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Introduction** : Definition of pesticides, brief history, pesticides registration, pesticide industries and markets in world and India. | 4 |
| **Unit 2.** | **Toxicology of pesticides** : $LD_{50}$ and $LC_{50}$ , Dose-response relationship; Carcinogenic, Mutagenic and Teratogenic effects, Method of testing chemicals on insect and evaluation of toxicity. | 4 |
| **Unit 3.** | **Group characteristics and function of pesticides :**Organochlorines, Organophosphorus insecticides, Carbamates, Pyrethroids, other plant origin bio-insecticides, neonicotinoids and nitrogenous insecticides; fumigants; IGRs, attractants, repellents and anti-feedants. Properties of few individual insecticides i.e. DDT, HCH (BHC), Lindane, Endosulfan, Parathion, Malathion, Carbaryl, Cypermethrin, etc. | 10 |
| **Unit 4.** | **Mode of action :** Central Nervous system, Acetylcholinesterase and unknown modes of action.Metabolism of insecticides: Phase I and Phase II reactions and metabolism of other pesticides. | 10 |
| **Unit 5.** | **Toxicological symptoms of**Organochlorinres, Organophosphorus, Carbamates, Pyrethroids, plant origin insecticides and other bio-insecticides. | 8 |
| **Unit 6.** | **Safer pesticides:**Next generation molecules to be used as pesticides for plant protection and their chemistry.Nano-pesticides: Use of nano-pesticides in plant protection, delivery technology and their behaviour in different ecosystem.Therapy and antidotes: Type and severity of | 10 |

contamination and medical aid.

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|---|---|---|
| **Unit 7.** | **Ecology and biodiversity of insects:**Insect biodiversity and their functioning in Terrestrial and aquatic ecosystem, Restoration of terrestrial ecosystem using the soil biota. | 6 |
| **Unit 8.** | **Global environmental impact on insects:**Impact of global climatic changes on insect behavior, physiology and reproduction. | 4 |
| **Unit 9.** | **Toxic chemicals and survival of insects:**ImpactofPesticides, Heavy Metals, Pharmaceuticals and other pollutants on insect physiology, their survival, reproduction and biodiversity. | 4 |

**Suggested Literature:**

1. Toxicology and Risk Assesssment: A Comprehensive Introduction, Greim H., and Snyder, R. (ed), John Wiley and Sons, UK
2. The Complete Book of pesticide management, Whitford, F., Wiley Interscience, John Wiley and Sons, UK
3. Safer Insecticides, Hodgson, E., and Kuhr, R. J., (ed), Marcel Dekker Inc., New York, USA
4. Pesticide Application Methods, Matthews, G, A., Blackwell Science, London, UK
5. Pesticide Biochemistry and Physiology, Wilkinson, C. F., Plenum Press, New York, UK
6. Metabolic pathways of agrochemicals Part II, Roberts, T. R., and Hutson, D. H. The Royal Society of Chemistry, UK
7. Chemical Ecology of Insects, Carde, R. T., and Bell, W. J., Chapman & Hall, New York, USA

**Course Learning Outcomes:**

- The students having this course will study various types of insecticides and understand their mode of action to kill/control the insects. Also, the students will learn about novel categories of insecticides that may be compatible with other control strategies.
- The students will come to know about many biorational insecticides and other eco-friendly methods for insect pest control, that may be combined to develop an appropriate IPM which has promising future perspectives.
- The students will learn handling of the pesticides in crop protection and understand the therapy and antidotes at the time of poisoning.
- Further, Insects being the important component of various food chains/ food webs, the students will be understand their crucial role in homeostatic maintenance of ecosystems and their biota. The students will learn about the impact of anthropogenic pollutants and climatic changes on the survival and propagation of insects, and may appreciate the insects as bio-indicators of ecological changes/disturbances.

## MS ZOOLE-4104: Agricultural & Medical Entomology

### Course Objectives:

The Agricultural Entomology course describes the interaction of nature, plants and insects in order to understand the gravity of pest problem on standing crops and harvested yields and highlights various control methods to ensure crop protection by controlling insect pests of important crops. The course describes adverse effects of pesticides and management of crop pests by an Integrated Pest Management (IPM) approach.

Medical Entomology will highlight the direct injuries and diseases caused by arthropods (phobias, annoyance, allergies, toxins, venoms and myiasis, arthropod transmission of vertebrate parasites and pathogens).

The course offers information on transmission of diseases, methods of surveillance for diseases, effective Integrated Management of Vector control and other methods of prevention of arthropod borne diseases.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Agricultural Entomology:**Agricultural pests: Pest status and factors responsible for achieving the status of pest, economic injury level, economic threshold, action threshold, pest spectrum, pest complex, carrying capacity, secondary pest outbreak, pest surveillance and sampling. | 6 |
| **Unit 2.** | **Insect Plant Interactions** - Theory of co-evolution, role of allelochemicals in host plant mediation, tritrophic interaction, host-plant selection by phytophagous insects, establishment of insect population on a plant surface." | 5 |
| **Unit 3.** | **Crop pests biology & control**: Identification, seasonal history, nature of damage and control measures of pests, of cereals, pulse crops, cotton, vegetables (summer vegetable and winter vegetable), oil seeds, fruit crops, sugarcane and stored grains. | 6 |
| **Unit 4.** | **Locusts-** different species and phases, phase transition, periodicity, migration, biology and control measures. | 4 |
| **Unit 5.** | **Integrated Pest Management**: Physical, Cultural, Chemical, Biological control, Genetic methods (SIT,F1 sterility, etc) and biotechnological methods of pest control.Biorational methods (Using Pheromones, JH mimics, MH agonists, etc) in pest management. | 8 |
| **Unit 6.** | **Stored grain pests**: Control and quarantine. | 2 |
| **Unit 7.** | **Plant resistance to insects**: types of resistance, mechanism of resistance-antibiosis, antixenosis, tolerance, factors mediating resistance. Transgenic plants (using genes of *Bacillus thuriengensis* ,etc) by recombinant DNA technology, resistance management of *Bt*-crops. | 6 |
| **Unit 8.** | **Medical Entomology:** Introduction-**V**ector biology, medical importance and management of the medically important insects (fleas, lice, bugs, mosquitoes and flies); Modes of | 15 |

transmissionofarthropod borne communicable diseases; Epidemiology of Vector-Borne diseases through Parasites and Pathogens of Public Health Importance- Occurrence, causative agents, transmission and control of protozoan, bacterial, rickettsial and viral diseases. e.g Malaria, Leishmaniasis, Sleeping sickness, Filariasis, Plague, Japanese Encephalitis, Yellow fever, Dengue, Chikungunya; Ecto-&endoparasites- of skin, Internal Insect Parasites (myiasis causing insects).

| | | |
|---|---|---|
| **Unit 9.** | **Control of insect vectors of public health importance**: Management of Vector-Borne Diseases by Integrated Vector Managemen. | 3 |
| **Unit 10.** | **Forensic Entomology**: Forensically important insects, role of insects/arthropods in criminal investigation, by predicting time and cause of death. | 3 |

**Suggested Literature:**

- Insect Plant Biology, Schoonhoven, L. M., van Loon, J.A., &Dicke, M., Publisher Oxford University Press, USA
- Interrelationship between insects and Plants, Jolivet, P., CRC Press, USA
- Entomology & Pest Management, Pedigo, L. P.,Prentice Hall, New Jersey, USA
- Concepts of IPM, Norris, Caswell-Chen and Kogan, Prentice-Hall, USA
- Agricultural insects pests of the tropics and their control, Hill, D. S., Cambridge University Press, UK
- Medical and Veterinary Entomology Mullen, G. ,Durden, L., Academic Press, USA
- Medical and Veterinary Entomology, Kettle, D. S., Cabi Press, USA
- Medical Entomology for students, Service, M. Cambridge University Press, UK .

**Course Learning Outcomes:**

- Agricultural Entomology plays a major role in training students in understanding the interaction of nature, plants and insects in order to ensure crop protection by controlling economically important insect pests of various crops. The course study makes the students capable to learn ill effects of pesticides and management of crop pests by bio-rational methods in an integrated approach (IPM) and impart concerned knowledge to the farmers and get involved in various pest management organizations.

## MS ZOOLE-4105P: Practicals in Entomology

1. Morphology: Study of head and its sclerites of honeybee and cockroach.
2. Study of mouth parts of cockroach, housefly, honeybee, mosquito and butterfly.
3. Study of wings and their venation, Different types of antennae and legs of insects.
4. Study of stinging apparatus of honey bee.
5. Taxonomy: Identification of insects belonging to different groups up to orders and sub orders.
6. Social Insects: Morphological studies of various castes of Polistes, Apis, Camponotus, and Odontotermes.
7. Study of various types of social insects and their nests.
8. Dissection of alimentary canal of Dysdercus, honeybee, butterfly and grasshopper.
9. Reproductive system: Dissection of male & female reproductive system of moths; Apyrene&Eupyrene sperm in moths.
10. Filter chamber of homopteran; salivary glands of mosquito, honeybee and Dysdercus.
11. Excretory system detection of uric acid in malpighian tubules, uptake of dye in malpighian tubules.
12. Circulation: haemocyte count, estimation of protein in hemolymph.
13. Respiratory system: dissection of butterfly, Dysdercusand grasshopper.
14. Nervous system: dissection of Dysdercus, butterfly, honey bee and locust, stomodeal nervous system of cockroach and grasshopper.
15. Insect Toxicology: Estimation of LD50 and LC 50 using insects.
16. Pesticide residue analysis of contaminated soil, vegetable and water using TLC, GLC and HPLC.
17. Studies on dissipation of pesticides from soil and half life estimation.
18. Estimation of uncertainty and variability in pesticide residue analysis.
19. Estimation of acetylcholinestarase activity to evaluate the toxicity of xenobiotic compounds.
20. Ecology: Measuring insect microclimate
21. Life tables/population dynamics modeling
22. Agricultural Entomology: Collection and identification of economically important insects and various stages of their life history.
23. Methods of rearing insects in the laboratory.
24. Identification of important insect pests of different crop plants and stored products.
25. Visits to agricultural fields and forests for on spot study of pests and damage caused by them.
26. Vector Biology: Study of life history stages of medically important arthropods, Diptera, Phthiraptera, Siphonoptera.
27. Identification and anatomical studies of major vector species of Anopheles, Culex and Aedes.

28. Field collection of immature stages of mosquitoes. Study of few available pathogens of arthropod-borne diseases.

## Stream 2: FISH BIOLOGY

## MS ZOOLE-4201: Diversity and Behaviour of Fishes

### Course Objectives:

**Diversity and Behaviour of Fishes** introduces the young students to the world of fish diversity. Globally, more than 28000 fish species are available and India has huge fish biodiversity.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Origin, Evolution and Distribution** of major groups of fishes, Evolutionary Strategies, Gene and Genome Duplication, Evolutionary Genetics, Biogeographical Distribution, Methods employed in Phylogenetic Studies and Fish Identification. | 15 |
| **Unit 2.** | **Comparative anatomy** of skin, scales and fins, digestive system, circulatory system, respiratory system including accessory respiratory organs, urinogenital system and immune system. | 25 |
| **Unit 3.** | **Behaviour** in relation to feeding, schooling, migration, courtship, mating and parental care. Adaptations and Symbiotic associations. | 10 |
| **Unit 4.** | Sources of **Aquatic Pollution**, Impact of pollution on aquatic organisms, Impact of exotic fish species and GMOs on aquatic biodiversity, Fishes and their relationship with abiotic and biotic factors. | 10 |

### Suggested Literature:

1. Biology of Fishes. 2008. Bone, Q. and Moore, R., Talyor and Francis Group, CRC Press, U.K.
2. The Diversity of Fishes. 1994. G.S. Helfman, B.B. Collette & D.E. Facey (Eds) Blackwell Sceince, USA.
3. Readings in Ichthyology. 1979. M.S. Love and G.M. Cailliet (eds). Prentice-Hall of India.
4. The Senses of Fish Adaptations for the Reception of Natural Stimuli. 2004. von der Emde, R., Mogdans, J. and Kapoor, B. G., Narosa Publishing House, New Delhi, India.

### Course Learning Outcomes:

- Students will learn the identification of fishes using classical morphological method as well as advanced molecular tools (viz. barcoding).

## MSZOOLE-4202: Fish Physiology

### Course Objectives:

Various physiological aspects of fish viz. respiration, feeding, digestion, reproduction, immunology, etc. are included in the second paper, **Fish Physiology**

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Swimming and Buoyancy**: Propulsive systems, swimming modes, strategies for buoyancy regulation. | 4 |
| **Unit 2.** | **Internal Transport and Homeostasis**: Gas exchange. Aquatic and aerial respiration.cardiovascular physiology, osmoionic regulation. Acid-base balance. | 14 |
| **Unit 3.** | **Growth and Metabolism**: Regulation of food intake by neuropeptides and hormones, environmental factors and feed intake, digestive physiology and nutrient digestibility in fishes, nutritional energetic. | 6 |
| **Unit 4.** | **Immunity**: Development of immune system, cells and tissues of the fish immune system, Modulators of fish immune responses, Humoral and cell mediated immune defense, Fish antibody molecules and their effector functions. Host-parasite interaction, immune-evasion mechanisms of fish pathogens. | 10 |
| **Unit 5.** | **Sensory Physiology and Coordination**: Photoreception, Olfaction, Perception of mechanical and electrical stimuli, Endocrine glands and neuroendocrine coordination. | 8 |
| **Unit 6.** | **Reproductive physiology**: Reproductive strategies, Environmental factors regulating reproductive cycles, Hormonal and molecular mechanisms of oogenesis and spermatogenesis, Ovulation, spawning and spermiation, Fertilization and development. | 14 |
| **Unit 7.** | **Stress Physiology**: Effect of abiotic, biotic and xenobiotic stresses on fish immunesystem, Adaptation to extreme temperature, Hypoxia. | 4 |

### Suggested Literature:

1. Encyclopedia of Fish Physiology. 2011. Anthony P. Farrell, E.D. Stevens, J.J. Cech& J.G. Richards (Eds). Academic Press, UK.
2. Fish Physiology. (Series) W.S.Hoar and D.J. Randall (Series Eds). Academic Press, UK.
3. The Physiology of Fishes. 2013. Evans, D. H. and Claiborne, J. D., Taylor and Francis Group, CRC Press, UK.

### Course Learning Outcomes:

- The knowledge of physiology equips the young generation for the propagation of fish. The students will be exposed to the modern immunological technique that is the need of the day to control disease related problems in the field.

## MS ZOOLE-4203: Aquatic Resources and their Conservation

### Course Objectives:

The paper **Aquatic Resources and their Conservation** gives information about the various aquatic resources viz. rivers, lakes, reservoirs, oceans.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Aquatic Resources**: Riverine fisheries, Cold water fisheries, Estuarine fisheries, Marine fisheries, Impact of interlinking of rivers on fisheries, Biology of commercially important fishes of India (sardine, mackerel, hilsa, mahseer). Survey of world fisheries, Origin of lakes and lake morphology. Light, temperature, oxygen and other dissolved gases in lakes, pH and redox potential in relation to the aquatic ecosystems. | 20 |
| **Unit 2.** | **Aquatic Organisms**: Distribution patterns of planktonic organisms.Phytoplankton-zooplankton relationships. Planktonic community organization in relation to predators.Adaptations of planktonic organisms to different aquatic habitats.Periphytic communities. Benthos. Bio-indicators and Biomonitoring. | 10 |
| **Unit 3.** | **Fishing Techniques**: Remote sensing, sonar, radar; crafts and gears. Fishways and screens. | 8 |
| **Unit 4.** | **Stock Assessment and Management**: Marking, Tagging and Population enumeration, Length-weight relationship, Age and growth, Fecundity estimation, Application of statistical methods in fisheries, Fish conservation and Fishing laws. | 10 |
| **Unit 5.** | **Post Harvest Technology** - Fish spoilage, rigor mortis, rancidity, enzymatic spoilage, microbial spoilage. Principles and methods of fish preservation, Problems associated with fish preservations, Processing and marketing of fish by-products, Qulaity control in fish processing industry. | 12 |

### Suggested Literature:

1. Computers in Fisheries Research, 2009. Megrey, B. A. and Moksness, E. Springer, USA.
2. Biological Invasions in Marine Ecosystems Ecological, Management and Geographic Perspectives. 2009. Rilov, G. and Jeffrey, A. C. , Springer-Verlag,Germany.
3. Handbook of Fisheries and Aquaculture. 2013. Indian Council of Agricultural Research, ICAR, DIPA, New Delhi, India.

### Course Learning Outcomes:

- The conservation of aquatic resources is most essential in the present scenario of climate change and anthropogenic activities. India has long coastline with many fish landing centres that help in the livelihood and income generation.

## MS ZOOLE-4204: Aquaculture

### Course Objectives:

Culture techniques of aquatic organisms form different aquatic resources (freshwater, estuarine and marine) are included in the fourth paper, **Aquaculture**. The environmental and nutritional requirements, reproduction and diseases of cultured species are the core parts of this paper. Various molecular techniques like transgenic fish production, genetic selection, hybridization, etc. are also included in this paper.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Culture of Fish and Shellfish**: Freshwater (carps, catfishes, prawns), brackish water (milk fish, mullets, crabs, shrimps), mariculture (mussels, oysters, sea weeds), fish food organisms (algae; *Artemia*; zooplankton). | 16 |
| **Unit 2.** | **Water-quality criteria for Aquaculture**: Role of temperature, pH, salinity, dissolved oxygen, ammonia, nitrite, nitrate, phosphate. | 4 |
| **Unit 3.** | **Integrated Farming**: Fish-cum-livestock farming, paddy-cum-fish farming. | 4 |
| **Unit 4.** | **Aquaculture Engineering:** Aquahouse, hatchery, ponds, race ways, recirculating system, cage, pen. | 4 |
| **Unit 5.** | **Fish Seed Technology and Transport**: Natural collection, Bundh breeding, Induced breeding, Global survey of fish breeding practices, Cryopreservation of gametes, Transport of eggs, fry, fingerlings and adults. | 8 |
| **Unit 6.** | **Nutrition of Aquatic Animals**: Nutritional requirements of commercially important finfish and shellfish, formulation of fish feed, feeding techniques, role of probiotics and prebiotics in fish nutrition | 8 |
| **Unit 7.** | **Role of Genetics in Aquaculture**: Gynogenesis, androgenesis, triploidy, tetraploidy, hybridization, sex reversal and breeding, production of transgenic fish. | 6 |
| **Unit 8.** | **Fish Health**: Infection and diseases in fish, common fish pathogens, and routes of pathogen entry in fish. Fish vaccines-strategy and use in aquaculture. | 4 |
| **Unit 9.** | **Environmental Impact of Aquaculture**: Aquacultural wastes and future developments in waste minimization, environmental consequences of hyper-nutrification. | 4 |
| **Unit 10.** | **Extension services**: Basic principles and emerging issues of extension, Role of information and communication technology. | 2 |

### Suggested Literature:

1. Fishponds in Farming Systems. 2007. Zijpp, V. D., Verreth, J. A. J., Tri, L. Q., van Mensvoort, M. E. F., Bosma, R. H., and Beveridge, M. C. M. Wageningen Academic Publishers, Netherlands.

2. Aquaculture Principles and Practices. 2005. Pillay, T. V. R. Second edition, Blackwell Publishing, USA.
3. Aquaculture and Fisheries Biotechnology Genetic Approaches. 2011. Dunham, R. A. CABI Publishing, USA.
4. Fish Defenses. Zaccone. 2010. G., Meseguer, J., Garcia-Ayala, A. and Kapoor, B. G. Science Publishers, USA.

**Course Learning Outcomes:**

- All the basic information gathered in three papers will be utilized in the fourth paper Aquaculture. The study of culture techniques of various aquatic organisms helps in the production of healthy food for human consumption in a sustainable manner and also in employment generation.

## MS ZOOLE-4205P: Practicals in Fish Biology

1. Phylogenetic analysis of bony fish: Morphological analysis; mtDNA polymorphisms; comparison of protein sequences and construction of phylogenetic tree.
2. Identification of fishes including a detailed study of Delhi fish fauna.
3. Identification of Indian common fish faunal resources from cold water, warm water, brackish water, marine water and ornamental fishes.
4. Types of scales, fins and otoliths.
5. Display of visceral organs; preparation of fish skeleton; alizarine preparation.
6. Dissection of Weberian ossicles and their association with internal ear and air bladder in representative fishes.
7. Comparative study of digestive enzymes of herbivore, carnivore and omnivore fishes.
8. Dissection of cranial nerves of selected fishes.
9. Study of accessory respiratory organs.
10. Collection of body fluids (blood sampling; urine collection; gamete collection).
11. Study of various hematological parameters. Isolation of phagocytes and phagocytosis.
12. Raising antibodies in fish and isolation of fish immunoglobulins.
13. Oxygen consumption in relation to body size/stress/anesthesia.
14. Bulk-staining of hypothalamic nuclei.
15. Extraction, isolation and characterization of plasma vitellogenin and egg-yolk proteins.
16. Gametogenesis and *in vitro* meiotic oocyte maturation.
17. Surgical procedures (effect of hypophysectomy on osmoregulatory parameters; effect of gonadectomy on fish).
18. Physico-chemical parameters (temperature, pH, conductivity, dissolved oxygen etc.) of freshwater bodies.
19. Biological analysis of water and estimation of primary productivity.
20. Quantitative and qualitative anlysis of phytoplankton and zooplankton from natural resources.
21. Study of benthic macroinvertebrates in natural water bodies.
22. Study of fishing gears and nets with the help of models.
23. Simulated experiments on population enumeration.
24. Determination of age and growth; Gonadosomatic index.
25. Length-weight relationship and condition factor determination.
26. Collection and identification of aquatic weeds and aquatic insects.
27. Demonstration of breeding pools and hatcheries.
28. Induced breeding of Indian major carps and catfishes.
29. Identification of eggs, spawn, fry and fingerlings of cultivable fishes of India.
30. Estimation of ovarian eggs.

31. Culture of live food organisms and assay of nutritional quality of live food.
32. Study of feeding habits of fishes by gut content analysis.
33. Formulation and preparation of practical diets for Indian major carps and prawns.
34. Molecular techniques in fish health management.
35. Visit to a fish market in Delhi, identification of dominant finfish and shellfish.
36. Visit to freshwater/ marine fish farm.

## Stream 3: Genomes and Evolution

## MS ZOOLE 4301: Genomics

### Course Objectives:

To effectively complete this paper, students should have a desire for deeper understanding of molecular genetics and molecular cell biology. The course is design to impart knowledge and understanding of this rapidly changing field of modern biology and fast evolving tools for whole genome analysis, high throughput genome, transcriptome and proteome sequencing. The course will focus on comparison between genomes, its advantages and implications in evolution and provide students thought-provoking platform to deduce functional relationships at all macromolecular levels i.e.DNA, RNA and proteins across animal kingdom.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Organization and structure of genomes**: size, complexity, gene-complexity, virus and bacterial genomes, organelle genome, architecture of mitochondrial genome, conserved chloroplast DNA; organization and nature of nuclear DNA in eukaryotes; transposable elements, retro-teaspoons, SINE, LINE, Alu and other repeat elements, pseudogenes, segmental duplications . | 15 |
| **Unit 2.** | **Mapping genomes**: physical maps, EST, SNPs as physical markers, radiation hybrids, FISH, optical mapping, gene maps, integration of physical and genetic maps; sequencing genomes: high-throughput sequencing, strategies of sequencing, recognition of coding and non-coding regions and annotation of genes, quality of genome-sequence data, base calling and sequence accuracy. | 15 |
| **Unit 3.** | **Bioinformatics**: datasets, sequence analysis based on alignment, de novo identification of genes, in silico methods. Comparative genomics - orthologs and paralogs, protein evolution by exon shuffling; human genome project, comparative genomics of bacteria, organelles, and eukaryotes. | 15 |
| **Unit 4.** | **Large scale mutagenesis and interference**: genome wide gene targeting; systematic approach, random mutagenesis, insertional mutagenesis, libraries of knock-down phenocopies created by RNA interference; transcriptome analysis, DNA micro-array profiling, data processing and presentation, expression profiling, proteomics - expression analysis, protein structure analysis, protein-protein interaction. Introduction to Pharmacogenomics, Metabolomics, Nutrigenomics. | 15 |

### Suggested Literature:

1. Recombinant DNA: Genes and Genomics – a short course, Watson et al., W. H.

Freeman and Company, New York, USA
2. Principles of Gene Manipulation and Genomics, Primrose, S. B. and Twyman, R.M., (7th Ed. 2006), Blackwell Publishing, West Sussex, UK
3. Molecular Biotechnology: Principles and application of recombinant DNA, Bernard R. and Jack, ASM Press, Herndon, USA

**Course Learning Outcomes:**

- After successful completion of the course the student should be able to design and comprehend experimental strategies for whole genome, transcriptome and proteome analysis. The student should be able to appropriately access and utilize various online and offline tools and databases related to genomic analysis.

## MS ZOOLE- 4302: Microbiome

**Course Objectives:**

The course will provide knowledge about different microbes living in specific niche, their interaction with each other and other living organisms

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Microbes:** (bacteria, virus, fungi and protozoa which colonize human and animal body), Role of Microbiome in health of Human, Development of Microbiome in human from mother to old age, Role of Genome, environment and lifestyle in development of microbiome. | 15 |
| **Unit 2.** | **Biodiversity and their function**: Importance of the communities of microorganisms that inhabit the human body. Human Pathogens and their mechanism of disease establishment, Micobiome and Immunity and their role in protection from pathogens, Cross-Talk Between Gut Microbiome and Host Metabolism Under Normal Physiological Condition. | 15 |
| **Unit 3.** | **HUMAN MICROBIOME:** Gut Microbiome and their role in digestion and nutrition, Skin and Oral Microbiome, Microbiome in other human tissues, Microbiome and Diseases, Virome in Health and Diseases, Mycome in Health and Diseases, Application of Microbiome in treatment of disease. | 15 |
| **Unit 4.** | **Pioneering projects in metagenomics** - the acid mine drainage project, the Sargasso sea metagenomics survey and community profiling, the antibiotic resistor project, viral metagenomics, metagenomics of insects | 15 |

**Suggested Literature:**

1. The course will be taught from papers published in "Nature, Science, Cell, Microbiome, Gut" and other journals

## MS ZOOLE 4303: RNA Biology

**Course Objectives:**

The course will provide knowledge about various types of RNA and their role in regulation of cellular processes.

**Course content:**

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Introduction**: Central Dogma of molecular Biology, Definition and types of non-coding RNA, Classification of non-coding RNA, RNA type/Key features/function/expression: level and tissue specificity/ key references. | 15 |
| **Unit 2.** | **RNA-RNA interactions Affintiy**: predicted; measured, G:U bonding, RNA structure: CalculationofdelG and effect of mismatch on bindingaffinity. | 15 |
| **Unit 3.** | **Evolution of ncRNA:** Classes of ncRNA in different branches of the treeof life, Conservation in different classes of RNA, Annotation a miRNA,piRNA, lncRNA, rRNA. Case study: Bacterial small RNA, Cancer andncRNA. | 15 |
| **Unit 4.** | **miRNA Biogenesis**: How do miRNAs function, Plant miRNA - Story of David Baulcombe's work, How do lncRNAs function? Overview: lncRNA sponges, CircularlncRNA, Scaffold for RNA binding proteins, Splicing & RNA, Chromatin and RNA, Putting ncRNA to work: Genome Editing. Genome Editing: CRISPR-CAS9 system, Synthetic RNA. | 15 |

**Suggested Literature:**

1. RNA Biology by Gunter Meister. Publisher: Wiley-VCH ISBN-10: 3527322787
2. Molecular Biology of RNA by David Elliott and Michael Ladomery. Oxford University Press, ISBN: 9780199671397.

**Course Learning Outcomes:**

The student will

- Understand various types of RNA
- Role of different RNA in cellular processes
- RNA Genomes
- RNA in Diseases

## MS ZOOLE 4304: Epigenetics and Trans -generational Inheritance

### Course Objectives:

In the year 2003 after the publication of first draft genome sequence of human, the famous Nobel Laureate James Watson commented that the excitement now lies in the field of chromatin and epigenetics. Though the mechanism of epigenetics inheritance in not fully understood, but it is clear that the genes and genomics cannot solely explain the phenomenon such as developmental differentiation and many behavior change and adaptations. The 3-D arrangements of DNA in the nucleus, histone modifications and non-coding RNA now make a strong basis for regulation beyond genomics. Therefore, the course on Epigenetics and trans generational inheritance aims to aquatint students with recent advances in the field that covers inheritance beyond genomics.

It is assumed that a student who opts for this course has already taken up the advance courses in the genetics, structure and function of genes and genomics.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Chromatin structure** - basic organization of a eukaryotic genome; histone - structure and function; nucleosome as the fundamental particle; 30 nm chromatin fibers, higher order structure of chromatin, chromatin-territories; Topologically Associated Domains and methods of their mapping, intra-nuclear spatial organization of chromatin. | **15** |
| **Unit 2.** | **Epigenetics - from phenomenon to field:** A brief history of epigenetics - overview and concepts; chromatin modifications and their mechanism of action, concept of 'histone- code' hypothesis, epigenetics in saccharomyces cerevisiae -mating type switch, MAT locus and heterochromatin formation, and gene silencing, RNAi and heterochromatin assembly, role of noncoding RNAs, ATP-dependent Chromatin remodeling and mechanisms. | 20 |
| **Unit 3.** | **Trans-generational Epigenetics Inheritance -**Chromatin structure and epigenetics marks –transcriptional silencing by polycomb group proteins , transcriptional regulation by trithorax group proteins, histone variants and epigenetics , epigenetic regulation of chromosome inheritance, Epigenetic inheritance of stress response. | 15 |
| **Unit 4.** | **Metabolic Reprogramming and Epigenetics -**Epigenetics and genome imprinting - DNA methylation in mammals, genomic imprinting in mammals, germ line and pluripotent stem cells, epigenetics and human disease, epigenetic determinants of cancer. | 10 |

### Suggested Literature:

1. Epigenetics, C. David Allis and Thomas Jenuwein, 2nd Edition (2015 )Cold Spring Harbor Laboratory Press, New York, USA
2. Molecular Biology of Gene, Watson et al., (7th Ed. 2014), Pearson Education,

Delhi, INDIA.
3. Lewin's Gene XII, JE Krebs et al, 2017, Jones & Bartlett Learning
4. Contemporary Review and Research articles published in leadi.ng Scientific Journals, such as Cell, Nature, Science and Trends journals.

**Course Learning Outcomes:**

- It is expected that the students after completing this course would acquire the theoretical and practical comprehensions for designing the research problems at higher level. They also would understand the connect the metabolic reprogramming and development of diseases through the lens of epigenetics, the only connecting link available as of now, and which attempts to give answers to the questions why.

## MS ZOOLE-4305P: Practicals in Genome and Evolution

1. Isolate genomic DNA.
2. PCR amplification and analysis by agarose gel electrophoresis.
3. Plasmid preparation
4. Restriction digestion and mapping.
5. Vector and insert ligation and PCR amplified product.
6. Transformation in E. coli with recombinant plasmid
7. Induction of cloned gene with IPTG and analysis on SDS-PAGE.
8. *In vitro* packaging of lambda DNA, transfection and plaque formation.
9. Southern hybridization of genomic DNA with suitable gene as probe.
10. Metagenomic DNA isolation from animal / soil samples.
11. Studying bacterial diversity from animal gut tissues by cloning and by RFLP
12. Studying bacterial diversity from animal gut tissues by Illumina/454 technique.
13. Assembling metagenomic reads from raw Illumina shotgun reads using IDBA or MetaVelvet.
14. Diversity analysis by bacterial marker based approach on shotgun data using Metaphlan.
15. Annotation of assembled metagenomiccontigs using MG-RAST.
16. Functional metagenomics using KAAA-KEGG and Minpath.
17. Studying antibiotic resistance profiles of bacteria from animal gut tissues.
18. Isolation of Total RNA, determination of its purity and concentration.
19. cDNA synthesis.
20. Isolation of microRNA
21. Amplification of specific microRNA by PCR
22. Isolation of nuclei (as a source for studies on structure of chromatin) from rat/mouse liver by discontinuous sucrose-density gradient centrifugation.
23. Isolation of total histones, and resolution on SDS-PAGE.
24. Studies on modifications of histones (such as acetylation, methylation etc.) by western-blotting using modification-specific antibodies.
25. Expression and purification of recombinant histones.
26. Isolation and characterization of total nuclear proteins.
27. Digestion of nuclei by MNase and calculation of ‘repeat-length’ of nucleosomes.
28. Digestion of nuclei by DNase-I, and studies of DNA superhelicity in the nucleosomes.
29. Preparation and characterization of soluble-chromatin (10 and 30 nm chromatin-fibers).
30. Purification of and characterization of mononucleosomes.
31. Reconstitution of nucleosome-core and PCR-amplified synthetic DNA.
32. Chromatin-immunoprecipitation (ChIP).
33. Promoter methylation study by bisulphite modification and methylation-specific PCR (MSP-PCR) method.

## Stream4: MOLECULAR ENDOCRINOLOGY AND REPRODUCTION

## MS ZOOLE 4401: Neuroendocrinology

### Course Objectives:

The course is open to students having Undergraduate degreee with Zoology as a subject and having background of Physiology. The aim of this course is to provide a comprehensive understanding of relationship of central nervous system with peripehral endocrine system and controlled functions system in higher vertebrates.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Introduction, History and Milestones:**General organization of central nervous system and brain in mammals,Type and structural characteristics of neurons, The information flow in the brain: connections and synapses, The transmitter systems:Amine neurotransmitters, Amino acid neurotransmitters, Peptide neurotransmitters. Principles and application of techniques used in neuroendocrinology (e.g. immunocytochemistry and *in situ* hybridization). | 15 |
| **Unit 2.** | **The Hypothalamus**: Hormones from hypothalamus, Chemistry and physiology of releasing and release-inhibiting hormones, Regulation of hypothalamic secretion, Environment and hypothalamus. **Development and cytology of the pituitary gland:** Regulation of pituitary hormone secretionsHypothalamo – hypophyseal axis, Adenohypophysis: Regulation of the release of adenohypophyseal hormones, Neurohypophysis: synthesis and storage of oxytocin and vasopressin. | 15 |
| **Unit 3.** | **The pineal gland:** Phylogeny and peculiarities of pinealocytes, Biosynthesis and regulation of melatonin secretion, Melatonin rhythms: daily and seasonal effects, Role of pineal in circadian physiology, Regulation of pineal secretion, Melatonin receptors, Physiological actions: Melatonin and neuroendocrine functions. | 15 |
| **Unit 4.** | **Hypothalamus and internal timing:**Neuroendocrinology of homeostasis and temperature regulation, Neuroendocrinology of hunger and satiety in mammals, Neuroendocrinology of the stress response, Neuroendocrine integration and immune function, Neuroendocrine control of seasonal processes, Neuroendocrinology of adolescence and puberty. | 15 |

### Suggested Literature:

1. Handbook of Neuroendocrinology: George Fink, Donald W. Pfaff and Jon E. Levine

(Eds.) 2012. Elsevier Inc.
2. An Introduction to Neuroendocrinology: Michael Wilkinson and Richard E Brown (2015), Cambridge University Press, UK.
3. Neuroscience: Exploring the Brain: 4th edition, Mark F. Bear, Barry W. Coonors and Michael A. Paradiso (2015). Wolters Kluwer.
4. Introduction to Behavioral Neuroendocrinology (5th edition), Randy J. Nelson and Lance J. Kriegsfeld (2016) Oxford University Press.

**Course Learning Outcomes:**

At the end of the course, the students should be able to

- Understand the basic organization of the verterbrate brain, and the interaction of hypothalamus with the pituitary and pineal gland.
- Learn basic principles of important techniques applied to neuroendocrine research.
- Understand neuroendocrine regulation of physiological processes.
- Develop the ability of critical thinking of regulatory biology in animals.

## MS ZOOLE- 4402: Environment, Epigenetics and Hormone action

### Course Objectives:

The course is planned to give comprehensive understanding of the responses to hormones and the mechanism of signalling. This course will provide an overview of the relationship of normal reproductive health with environment. The epigenetic changes due to the interaction of hormones and environment along with their trans-generational effects on the reproductivehealth will be discussed in higher vertebrates.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Discovery of hormones** as chemical signals for control and regulation of physiological processes. Major questions in biology of hormones. Structure of peptide, protein and glycoprotein hormones. Biosynthesis of protein hormones. Storage and secretion of hormones, molecular mechanisms of regulation of biosynthesis and secretion. Inhibitors of hormone biosynthesis and their use. Purification and characterization of protein hormones. Structure-function relationships in different hormones and the latest technologies to study the hormone receptor binding and signal detection like BRET/FRET. Techniques for quantitation of hormones. Design and development of hormonal assays. | 15 |
| **Unit 2.** | **The mechanism of action** of protein hormones and signal attenuation/desensitization. Signal discrimination, signal transduction and signal amplification in hormone regulated physiological processes. Activation and inhibition of adenylatecyclase, control of gene transcription. Mechanism of tyrosine kinase receptor action, Insulin receptor signaling and EGF receptor signaling. Structural domains, receptor binding proteins, SH2/SH3 domains. Down-stream tyrosine kinase receptor signaling events- serine/threonine protein kinase cascades, Ras-activation of MAPK, alterations in cancer cell receptor signaling. Gonadal and non-gonadal actions of gonadotropins. | 15 |
| **Unit 3.** | **Overview of cell surface receptor structures:** receptor dimerization, clustering and interactions with membrane components, Receptor protein complexes involved in gene transcription. Epigenetic regulation of genes encoding peptide hormones or their receptors. Genetic, biochemical and molecular analysis of functional and structural domains within steroid receptors. Experimental approaches to examine properties of steroid ligand binding to receptors, hormone agonists/antagonists and medical uses, activation of nuclear receptors, and receptor localization. DNA binding properties of steroid receptors. Positive and negative regulation of gene expression by steroid receptor/transcription factor interactions, receptor/co- | 15 |

activator and receptor/co-repressor interactions.

| | | |
|---|---|---|
| **Unit 4.** | **Environmental influence on epigenetic mechanisms** involved in the regulation of hormone actions. The role of endocrine disruptor in the causation of subfertility or infertility in animal models or human population. Receptor agonists, antagonists and their applications. Pharmacokinetics of hormones and the applications of nanobodies as modulators of hormone action. Hormones and behavior- cellular and molecular actions of semiochemicals. Hormones as therapeutic agents. Unsolved problems in hormone biology. | 15 |

**Suggested Literature:**

1. Peer reviewed journal articles, monographs and reviews as and whenrecommended.
2. Endocrine and reproductive physiology, 4th edition, edited by Bruce A. White and Susan P. Porterfied,Paperback ISBN: 9780323087049 Copyright © 2013 Elsevier Inc.
3. Molecular Biology of Steroid and Nuclear Hormone receptors, edited by Freedman L.P., ISBN978-1-4612-1764-0, Birkhauser, Boston, USA, 1998.
4. Progress in Molecular Biology and translational science, Vol.143 gonadotropins from benchside to bedside, edited by T. Rajendra Kumar, 2016 ISBN: 978-0-12-801058-7, Elsevier Inc.2018
5. Signal transduction 3rd edition, Author :Ijsbrand Kramer, ISBN: 9780123948038 Academic press, 2015.

**Course Learning Outcomes:**

- Students of this class will be able to understand the importance of hormones in the maintenance of reproductive health in human and animals. This course will make them suitably knowledgeable to undertake the therapeutic research jobs in various pharmaceutical companies as well as in hospitals in addition to the IVF centers.

## MSZOOLE-4403: Gamete Biology

### Course Objectives:

This course is designed to impart knowledge to students on the fertility and contraception. The knowledge of the two sexes and their gametes will help the students to understand the process of fertilizations and the intricacies involved in the maintenance of fertility. Gamete preservation in cancer patients, and in the case of infertile partner makes it an essential for assisted reproductive technologies to be successful.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | Sex determination and differentiation: Sex determination: Mechanism of genotypic and epigamic sex determination,Sexual differentiation, Differentiation of gonad, Differentiation of genital tract, Stem cell renewal. | 10 |
| **Unit 2.** | Male reproductive system:Testis, Spermatogenesis: structural and molecular events, experimental approaches to study spermatogenesis, Seminiferous epithelial cycle.TheSertoli cell: structure and function, The Leydig cell: generation of Leydig cell, steroidogenesis, Leydig and Sertoli cell proliferation during foetal and postnatal development, Regulation of testicular functions, Epididymis, Epididymal maturation of spermatozoa, Capacitation, AcrosomeReaction and its regulation, Male sterility,Azoospermia, Oligozoospermia, Asthenozoospermia, Varicocele, Genetic basis for male infertility, mutational analysis in genes for hormones, receptor and gamete development. | 20 |
| **Unit 3.** | Female reproductive system: Ovary, Follicular development and selection, Role of extra-and intra-gonadal factors in folliculogenesis, Oocyte maturation and its regulation, Ovulation, factors involved in follicular rupture, Luteinization and luteolysis, Follicular atresia, Regulation of reproductive cycle in female, Menstrual cycle in human, Estrous cycle in rat, Estrous behaviour in cycling animals, Female reproductive disorder. | 20 |
| **Unit 4.** | Contraception: Natural method (Fertility awareness), Surgical, Physical/Barrier methods, Chemical methods, Immunocontraception. | 10 |

### Suggested Literature:

1. The Physiology of Reproduction, second edition, Vol 1 and 2, edited by Ernst Knobil and Jimmy D. Neil. *Raven Press*, 2014.
2. Male Reproductive Function, edited by Christina Wang. Kluwer *Academic Publishers*, 1999.
3. The ovary, edited by Solly Zuckerman Baron Zuckerman, Barbara J.

Weir, T. G. Baker. *Academic Press*.

4. The ovary, edited by Peter C.K. Leung and Eli Y. Adashi, Elsevier (Academic Press), 2004.
5. Cell and Molecular Biology of Testis, edited by Claude Desjardins and Larry L. Ewing. *Oxford University Press US*.
6. Reproductive Endocrinology: Physiology, Pathophysiology, and Clinical Management, edited by Samuel S. C. Yen, Robert B. Jaffe, Robert L. Barbieri. *Saunders publisher*.

Recent review articles published in various journals: "Endocrine Reviews / Reproduction / Biology of Reproduction / General and Comparative Endocrinology / Journal of Endocrinology

**Course Learning Outcomes:**

- Students studying this course will be able to understand the structure and function of gametes like eggs and sperms, their maintenance so the reproductive health in human and animals is maintained in good condition. This course will make them suitably knowledgeable to undertake the jobs in the assisted reproductive technology clinics in the hospitals in addition to the teaching institutions.

## MS ZOOLE-4404:Biology of Pregnancy, Parturition and Lactation

### Course Objectives:

This course will help the students to recognize the physiological changes in pregnancy and how they affect nutritional needs and feeding strategies, identify how alcohol, artificial sweeteners, caffeine, contaminants, nicotine and drugs affect maternal-fetal health during pregnancy and lactation. They will be able to define gestational diabetes, pregnancy-induced hypertension in preeclampsia and other disorders of pregnancy.

### Course content:

**Theory**

| Unit no. | Topics | Hours |
|---|---|---|
| **Unit 1.** | **Embryo implantation:** morphological, physiological and molecular aspects of embryo-uterine interactions, implantation window, mechanism of implantation. Differentiation of cytotrophoblasts to syncytiotrophoblasts. Mechanism of placentation and placental transport function.Maternal physiology during pregnancy, Maternal adaptation to pregnancy,Fetal-placental physiology.decidualization, molecular and morphological markers of endometrial receptivity. | 20 |
| **Unit 2.** | **Placental neuro-endocrine functions:** hormones of pregnancy and their mechanism of action. Prevention of menstruation during pregnancy. Parturition and its control, Lactation and its hormonal control. Inhibition of the hypothalamic gonadotropin-releasing hormone (GnRH) pulse center by suckling and prolactin, in turn suppression of the gonadotropins (luteinizing hormone [LH] and follicle-stimulating hormone [FSH]), leading to low levels of the ovarian sex steroids (estradiol and progesterone). | 20 |
| **Unit 3.** | **Maternal immune-suppression during pregnancy**: Role of hormones in the regulation of immune system during pregnancy. Theories and models of immune tolerance in the context of pregnancy. Autoimmune bases of infertility and pregnancy loss. | 10 |
| **Unit 4.** | **Parturition and its hormonal regulation**, Lactation, Metabolic homeostasis in human pregnancy and lactation. Nutrition and health during pregnancy and lactation, skeletal demineralization during lactation. Pathophysiological of pregnancy: Proposed mechanism of implantation failure, recurrent abortions, preeclampsia and Gestational diabetes. Developmental origins of health and diseases. | 10 |

### Suggested Literature:

1. Regulation of Implantation and Establishment of Pregnancy in Mammals, Editors: Rodney D Geisert, Fuller W. Bazer, ISBN 978-3-319-15856-3, Springer International Publishing, 2015.
2. Kovac CS and Kronenberg HM, Maternal-fetal calcium and bone metabolism

during pregnancy, puerperium and lactation. Endocrine Review **18:** 832–872, 1997.

3. Implantation and early development, Editors: Hilary Critchley, Ian Cameron and Stephan Smith, ISBN 9781107784680, Cambridge University press, 2014.
4. Implantation, Biological and Clinical Aspects, Editors: Michael G. Chapman, J. GedisGrudzinskas, Tim Chard, ISBN 978-1-4471-3531-9, Springer-Verlag, 1988.

**Course Learning Outcomes:**

- After attending this course work the students should be able to understand the complex hormonal regulation of pregnancy and how environment including the obesity, exposure to pollution can affect the development of the fetus as well as the outcome of the pregnancy. A lot of research is required in this area and the students will be highly knowledgeable to take up research as well as teaching positions in various research or academic institutes.

## MS ZOOLE-4405P: Practicals in Molecular Endocrinology and Reproduction

1. Preparation of brain for cryosection: Transcardial perfusion of rat and brain fixation
2. Cresyl violet (CV) staining of rat brain to identify different brain nuclei.
3. Study of important brain areas and hypothalamic nuclei involved in neuroendocrine regulation.
4. Demonstration of hypothalamo-hypophyseal portal system in rat brain
5. Identification of different neuropeptides and area of its localization in brain following immunohistochemical (IHC) methods.
6. Isolation of pituitary cells to study the effect of GnRH and its analogues in culture.
7. Extraction of rat/mice pituitary and study on the anterior pituitary histology.
8. Demonstration of the flow cytometry technique for its uses in the study of neuro-endocrinology.
9. Isolation of protein hormone and demonstration of bio- activity in an in vivo bio- assay (e.g. FSH and LH).
10. In vivo bio- assay for estrogen ortestosterone.
11. In vitro biochemical assay for a hormone (LH or PRL).
12. Effect of hCG on RNA content in ovary.
13. Quantitation of specific transcript (mRNA) after ovarian stimulation by hCG or FSH.
14. ELISA for any one hormone and estimation of plasma level.
15. Estimation of weight or biochemical parameter in a rat tissue (e.g. adipose, ovary, uterus).
16. Streptozotocin administered rat model for diabetes.
17. Molecular cloning of a gene of protein hormone.
18. Expression of recombinant protein hormone or hormone receptor in *E. coli*.
19. Isolation of genomic DNA and total RNA for study on methylation and miRNA
20. Histology of testis and ovary of different age groups of rats to understand the sequence of events related to spermatogenesis and folliculogenesis and ageing effect.
21. Gonadectomy and sex steroids replacement therapy to see the effect on accessory sex organs of rats.
22. Isolation of testicular cells and ovarian follicular cells.
23. In vitro experiments with different testicular cells to provide the direct evidence related to humoral and cellular control of testicular functions.
24. Induction of superovulation and oocyte retrieval from oviduct of immature rat/mouse.
25. Sperms count and motility: Role of epididymal proteins, mono- and divalent cations and pH in control of sperm motility.
26. Capacitation and acrosome reaction under experimental conditions.
27. Surgical sterilization of male and female rats.
28. Isolation of various stages of germ cells following flow cytometry, analysis of DNA content in germ cell population.
29. To identify the first of pregnancy in rats/mice.
30. Study on the induction of pseudo pregnancy in rat/mice.

31. Preparation of mammary fat pad slides to demonstrate the epithelial component and lymph node.
32. Preparation of histological slides of mammary gland and uterus.
33. The effect of nutrition on the health of pregnant rats/mice and on the birth weight of the pups.
34. Vaginal smear preparation to examine estrous cycle and pregnancy.
35. Identification of male and female pups and weaning after 21 days of birth.
36. Effects of environmental endocrine disruptors on the fertility after exposure at immature, young and adult rats/mice.
37. To study the effect of known contraceptive drugs on the histology of testis or ovary of adolescent and young rats/mice.
38. Surgical sterilization of male (vasectomy) and female rats (tubal ligation).
39. Effect of environmental factors/pollution on pregnancy in rats/mice.
40. Proteomic analysis of the placenta in rat/mice.