

Syllabus for the

(Revised on 14-05-2009)

M. Sc.

in

Zoology

(Four-Semester Course)

**Department of Zoology,
University of Delhi, Delhi - 110007**

University of Delhi

Examination Branch

Date: April 2, 2009
Course : M.Sc. – Zoology

Check List of New Course Evaluation for AC Consideration

S.No.	Parameters	Status
1	Affiliation	
2	Programme Structure	
3	Codification of Papers	
4	Scheme of Examinations	
5	Pass Percentage	
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MASTER OF SCIENCE
(ZOOLOGY)
TWO YEAR FULL-TIMES PROGRAMME

RULES, REGULATIONS AND COURSE CONTENTS

Department of Zoology

FACULTY OF SCIENCE

UNIVERSITY OF DELHI

DELHI – 110007

2009

MASTER OF SCIENCE

(ZOOLOGY)

TWO-YEAR FULL-TIME PROGRAMME

AFFILIATION

The proposed programme shall be governed by the Department of Zoology, Faculty of Science, University of Delhi, Delhi – 110007.

PROGRAMME STRUCTURE

The M.Sc. Programme is divided into two Parts as under. Each part will consist of two Semesters as given below.

		Semester-Odd	Semester-Even
Part I	First Year	Semester – 1	Semester – 2
Part II	Second Year	Semester – 3	Semester – 4

Each semester would consist of four papers. Semesters I and II (Part I) would have Core Papers to be studied by all students of the M.Sc. – Zoology programme. Semesters III and IV (Part II) would comprise Optional Papers from which each student would have to select four papers in Semester III and three papers of his/her choice in Semester IV. Selection of papers in Semesters III and IV would be based on merit (performance in the Part I Examinations), choice and other specific guidelines as outlined below. It is mandatory for each student to complete a Dissertation, assigned at the end of 2nd Semester and goes on until 4th semester. It would be theoretical and not involve any laboratory components.

The schedule of papers prescribed for various semesters shall be as follows:

PART I: Semester – 1

1	ZOOL 101	Genetics and Cytogenetics
2	ZOOL 102	Principles of Gene Manipulation
3	ZOOL 103	Comparative Animal Physiology
4	ZOOL 104	Metabolism: Concepts and Regulation

PART I: Semester – 2

1	ZOOL 201	Developmental Biology
2	ZOOL 202	Systematics, Biodiversity and Evolution
3	ZOOL 203	Immunology
4	ZOOL 204	Molecular Cell Biology

PART II: Semester – 3

Two papers ZOOL 301 and ZOOL 302 (inter-disciplinary) are compulsory.

Two optional papers are to be selected by each student:

- **One paper from ZOOL 303, ZOOL 304 or ZOOL 305**
- **One paper from ZOOL 306, ZOOL 307 or ZOOL 308.**

1	ZOOL 301	Principles of Ecology	} Interdisciplinary
2	ZOOL 302	Computational Biology, Biostatistics and Bioinformatics	
3	ZOOL 303	Biology of Parasitism	
4	ZOOL 304	Chronobiology	
5	ZOOL 305	Protein Structure, Function and Evolution	
6	ZOOL 306	Structure and Function of Genes	
7	ZOOL 307	Animal Behavior	
8	ZOOL 308	Comparative Endocrine Physiology	

PART II: Semester – 4

Student will select any one of the four streams each stream consisting of three papers. Besides this, each student will complete a Dissertation, which would be theoretical and not involve any laboratory components.

Stream 1

		Entomology
1	ZOOL 4101	Insect Diversity, Society and Evolution
2	ZOOL 4102	Insect Physiology, Toxicology and Vector Biology
3	ZOOL 4103	Insect Ecology and Agricultural Entomology

Stream 2

		Fish Biology
1	ZOOL 4201	Evolution and Functional Anatomy of Fish
2	ZOOL 4202	Aquatic Resources and Their Conservation
3	ZOOL 4203	Aquaculture

- 4.2.1 Project work would be assigned at the end of Semester II to enable students to initiate work on the same.
 - 4.2.2 It would formally begin from Semester III and shall be theoretical in nature. This component would be evaluated for 100 marks.
 - 4.2.3 There shall be a viva-voce examination (conducted by a board of faculty members) at the end of Semester IV on the Dissertation that shall be evaluated for 50 marks.
5. 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

Minimum marks for passing the examination in each semester shall be 40% in each paper and 45% in aggregate of a semester.

However, a candidate who has secured the minimum marks to pass in each paper but has not secured the minimum marks to pass in aggregate may reappear in any of the paper/s of his choice in the concerned semester in order to be able to secure the minimum marks prescribed to pass the semester in aggregate.

No student would be allowed to avail of more than two chances to pass a paper inclusive of the first attempt.

PROMOTION CRITERIA

SEMESTER TO SEMESTER: Students shall be required to fulfill the Part to Part Promotion Criteria. Within the same Part, students shall be allowed to be promoted from a Semester to the next Semester, provided she/he has passed at least half of the courses of the current semester.

PART I TO PART II: Admission to Part II of the programme shall be open to only those students who have successfully passed at least 75% papers out of papers offered for the Part I courses comprising of Semester-1 and Semester-2 taken together. However, she/he will have to clear the remaining papers while studying in Part-II of the programme.

DIVISION CRITERIA

Successful candidates will be classified on the basis of combined results of Part-I and Part-II examinations as follows:

Candidates securing 60% and above	:	Ist Division
Candidates securing between 49.99% and 59.99%	:	IInd Division
All others	:	Pass

QUALIFYING PAPERS

None

SPAN PERIOD

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

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.

COURSE CONTENT FOR EACH COURSE

Submitted earlier

LIST OF READINGS

Submitted earlier

M. Sc. (Zoology)

Course No.		Page No.	Credits (T+Tu+P)
Semester 1			
ZOOL 101	Genetics and Cytogenetics	(1)	3+1+2
ZOOL 102	Principles of Gene Manipulation	(3)	3+1+2
ZOOL 103	Comparative Animal Physiology	(5)	3+1+2
ZOOL 104	Metabolism: Concepts and Regulation	(7)	3+1+2
Semester 2			
ZOOL 201	Developmental Biology	(9)	3+1+2
ZOOL 202	Systematics, Biodiversity and Evolution	(12)	3+1+2
ZOOL 203	Immunology	(14)	3+1+2
ZOOL 204	Molecular Cell Biology	(17)	3+1+2
Semester 3	(Any two combination : one from ZOOL 303 - ZOOL 305 and one from ZOOL 306 - ZOOL 308)		
ZOOL 301	Principles of Ecology	(19)	3+1+2
ZOOL 302	Computational Biology, Biostatistics and Bioinformatics	(21)	3+1+2
ZOOL 303	Biology of Parasitism	(24)	3+1+2
ZOOL 304	Chronobiology	(26)	3+1+2
ZOOL 305	Protein Structure, Function and Evolution	(28)	3+1+2
ZOOL 306	Structure and Function of Genes	(30)	3+1+2
ZOOL 307	Animal Behavior	(32)	3+1+2
ZOOL 308	Comparative Endocrine Physiology	(34)	3+1+2
Semester 4	Any One Stream from 1-4		3+1+2
Stream 1			
Entomology			
ZOOL 4101	Insect Diversity, Society and Evolution	(36)	3+1+2
ZOOL 4102	Insect Physiology, Toxicology and Vector Biology	(38)	3+1+2
ZOOL 4103	Insect Ecology and Agricultural Entomology	(40)	3+1+2
Stream 2			
Fish Biology			
ZOOL 4201	Evolution and Functional Anatomy of Fish	(42)	3+1+2
ZOOL 4202	Aquatic Resources and Their Conservation	(44)	3+1+2
ZOOL 4203	Aquaculture	(46)	3+1+2
Stream 3			
Genomics, Metagenomics and Epigenetics			
ZOOL 4301	Genomics	(48)	3+1+2
ZOOL 4302	Metagenomics	(50)	3+1+2
ZOOL 4303	Epigenetics and Chromatin Biology	(52)	3+1+2
Stream 4			
Molecular Endocrinology and Reproduction			
ZOOL 4401	Neuroendocrinology	(54)	3+1+2
ZOOL 4402	Molecular Endocrinology	(57)	3+1+2
ZOOL 4403	Biology of Reproduction	(59)	3+1+2
ZOOL 4004	Dissertation **		6

*Interdisciplinary courses to be taught by Zoology or Botany or Guest Faculty

** (Assigned at the end of 2nd Semester and goes until 4th semester. It would be theoretical and not involve any laboratory components)

T - Theory, Tu-Tutorial, P-Practicals

ZOOL 101: Genetics and Cytogenetics

Theory

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; nature of the gene and its functions: evolution of the concept of the gene, fine structure of gene (rII locus); methods of gene mapping: 3- point test cross in *Drosophila*, gene mapping in humans by linkage analysis in pedigrees.

Gene mutation and DNA repair: types of gene mutations, methods for detection of induced mutations, P- element insertional mutagenesis in *Drosophila*, DNA damage and repair; regulation of gene activity in *lac* and *trp* operons of *E. coli*, general introduction to gene regulation in eukaryotes at transcriptional and posttranscriptional levels, organization of a typical eukaryotic gene, transcription factors, enhancers and silencers, non coding genes.

Sex determination and dosage compensation: sex determination- in humans, *Drosophila* and other animals; dosage compensation of X-linked genes- hyperactivation of X-linked gene in male *Drosophila*, inactivation of X-linked genes in female mammals; human genetics- karyotype and nomenclature of metaphase chromosome bands; chromosome anomalies and diseases- chromosomal anomalies in malignancy (chronic myeloid leukemia, Burkitt's lymphoma, retinoblastoma and Wilms' tumor); genetic analysis of complex traits - complex pattern of inheritance, quantitative traits, threshold traits; human genome and mapping.

Genetics and cancer: oncogenes- tumor inducing retroviruses and viral oncogenes; chromosome rearrangement and cancer; tumor suppressor genes- cellular roles of tumor suppressor genes, p^{RB} , p^{53} , p^{APC} , genetic pathways to cancer.

Suggested Literature:

1. Principles of Genetics, Snustad and Simmons, (4th Ed. 2005), John Wiley & Sons, USA
2. Modern Genetic Analysis: Integrating Genes and Genomes, Griffiths, J.F., Gelbart, M., Lewontin, C. and Miller, W. H. Freeman and Company, New York, USA
3. Genetics, J. Russell, Benjamin-Cummings Publishing Company, San Francisco, California, USA

ZOOL 101: Genetics and Cytogenetics

Practicals

1. Study of mutant phenotypes of *Drosophila*.
2. Demonstration of law of segregation using *Drosophila* mutants.
3. Study of law of independent assortment.
4. Demonstration of sex- linkage by using *white* mutation of *Drosophila*.
5. Demonstration of dosage compensation in *Drosophila* males and females.
6. Demonstration of Green Fluorescence and Red Fluorescence protein for monitoring gene expression.
7. Targeted tissue specific expression of a gene using UAS-Gal4 System in *Drosophila*.
8. Preparation and study of metaphase chromosomes from mouse bone marrow:
 - a. Chromosome banding (C, G, H banding).
 - b. Study the differences in number, shape and size of chromosomes in normal vs. tumor cells, or normal vs. irradiated cells.
 - c. Preparation of human karyotype and study of chromosomal aberrations with respect to number, translocation, deletion etc. from the pictures provided.
9. Study of transcriptional activity in polytene chromosome upon heat shock induction by uridine incorporation.
10. Study of sex chromatin in buccal smear and hair bud cells (Human).
11. Study of Hardy– Weinberg equilibrium in human population by taking the example of blood group system (ABO).

ZOOL 102: Principles of Gene Manipulation

Theory

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.

Basic biology of cloning vectors: 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.

Principles of DNA sequencing, automated sequencing methods; synthesis of oligo-nucleotides, primer design; micro-arrays; confocal microscopy; changing genes- directed evolution, protein engineering in microbes .

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.

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

ZOOL 102: Principles of Gene Manipulation

Practicals

1. Plasmid DNA isolation: minipreps.
 2. Agarose gel electrophoresis of isolated plasmid.
 3. DNA quantization and purity of DNA.
 4. Restriction enzyme digestion of plasmid DNA.
 5. Purification of DNA from an agarose gel.
 6. Vector and insert ligation.
 7. Preparation of competent cells and storage.
 8. Transformation of *E. coli* with standard plasmids, calculation of transformation efficiency.
 9. Polymerase Chain Reaction, using standard 16S rRNA eubacterial primers.
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ZOOL 103: Comparative Animal Physiology

Theory

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.

Osmoregulation– Osmoregulation in aquatic and terrestrial environments, Kidney functions and diversity, 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. Adaptations to Stress- basic concept of environmental stress, acclimation, acclimatization, avoidance and tolerance, stress and hormones.

Sensing the Environment- photoreception, chemoreception, mechanoreception, echolocation, Endogenous and exogenous biological rhythms, Chromatophores and bioluminescence.

Feeding mechanisms and their control, effect of starvation. Muscle physiology – striated and smooth muscle, Adaptations of muscles for various activities, Neuronal control of muscle contraction, Electric organs.

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

ZOOL 103: Comparative Animal Physiology

Practicals

1. Observe and compare the inherent rhythmicity of the different parts of the heart.
 2. Determine the effects of application of parasympathetic or sympathetic agonists/ antagonists.
 3. Assessing physical and chemical modifiers of heart rate in frog.
 4. Determine the response of the heart to direct electrical stimulation / vagal stimulation.
 5. Effects of drugs and hormones on contraction of smooth muscles.
 6. Demonstration of tetany, action current and fatigue in muscle.
 7. To study the effect of load on muscle contraction.
 8. Concentration / dispersal of pigment in isolated scales of dark / light adapted fish.
 9. To examine the relative activity of enzymes in the fore, mid, and hindgut of a typical insect and to correlate the enzyme activity with gut regions.
 10. To determine the median threshold concentration of sucrose for housefly population.
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ZOOL 104: Metabolism – Concepts and Regulation

Theory

The living state, metabolism as the defining characteristic of living organisms, molecular approach to understanding life forms and living processes, biomolecule identification, separation and quantization, dynamic state of body constituents, experimental approaches to study metabolism.

A broad outline of metabolic pathways and their linkage, metabolism of primary metabolites – monosaccharides, lipids, amino acids and nucleotides.

Nature of enzymes – kinetics, reaction mechanism of chymotrypsin and lysozyme, purification and physico – chemical characterization, regulation of enzyme activity.

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.

Suggested Literature:

1. Biochemistry and Molecular Biology, Elliott and Elliott, Oxford University press, New York, USA (Indian edition)
 2. Harper's Illustrated Biochemistry, Murray, Granner and Rodwell, (27th Ed.), McGraw Hill, New York, USA
 3. Practical Biochemistry – Principles and Techniques, Wilson and Walker, Cambridge University Press, Cambridge, UK
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ZOOL 104: Metabolism – Concepts and Regulation

Practicals

1. Titration of an amino acid, an acidic dye and an organic acid to determine the pKa value.
 2. Preparation of a 'Good' buffer.
 3. Biomolecules.
 4. Sub-cellular fractionation of rat liver and marker enzyme assays.
 5. Purification of any one enzyme to homogeneity.
 6. Characterization of a purified protein/ enzyme for homogeneity by HPLC-GPC, molecular size by SDS-PAGE and post-translational modification by MALDI-TOF.
 7. Estimation of a sugar, an amino acid, a vitamin, a nucleotide/nucleic acid by appropriate chemical and biological methods.
 8. Kinetic characterization of any one enzyme.
 9. Determination of energy of activation for an enzyme mediated reaction.
 10. Surviving tissue technique and metabolic labeling using radioisotope containing precursor.
 11. Enzymes as drug targets- a selected example.
 12. Zymogram for any one enzyme.
 13. Immobilization of an enzyme and its study.
 14. Affinity chromatography using either a lectin or a textile dye.
 15. Allosteric regulation of an enzyme activity.
 16. Histochemical localization of a dehydrogenase.
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ZOOL 201: Developmental Biology

Theory

History and basic concepts: the origin of developmental biology- cell theory, mosaic and regulative development, discovery of induction, genetics and development; basic concepts of developmental biology- cell division, cell differentiation, signaling, patterning; model systems: vertebrates model organism- *Xenopus laevis*, chicken, mammals, zebrafish; invertebrate model organism- *Drosophila melanogaster*, *Caenorhabditis elegans*; identification of developmental genes: spontaneous and induced mutation, mutant screening, developmental mutations in *Drosophila*.

Early embryonic development of vertebrates and invertebrates: structure of the gametes– the sperm, the egg; cleavage and gastrulation; axes and germ layers; morphogenesis– cell adhesion, cleavage and formation of blastula, gastrulation, neural tube formation, cell migration; Axis specification in *Drosophila*; origin of anterior-posterior and dorsal- ventral patterning- role of maternal genes, patterning of early embryo by zygotic genes; segmentation genes- the gap genes, the pair– rule genes, the segment polarity genes, the homeotic selector genes- bithorax and antennapedia complex.

General concepts of organogenesis: development of chick limb- development and patterning of vertebrate limb, proximal- distal and dorso- ventral axis formation, homeobox genes in patterning, signaling in patterning of the limb; insect imaginal disc– determination of wing and leg imaginal discs, organizing center in patterning of the wing, butterfly wing development, the homeotic selector genes for segmental identity; insect compound eye– morphogenetic furrow, ommatidia, signaling, eyeless gene; kidney development– development of ureteric bud and mesenchymal tubules.

Postembryonic development: growth- cell proliferation, growth hormones; aging- genes involved in alteration in timing of senescence; regeneration– epimorphic regeneration of reptile (salamander) limb, requirement of nerves for the proliferation of blastema cells; embryonic stem cells and their applications; 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 nuclear RNA processing, inborn errors of translation; teratogenesis- environmental assaults on human development- teratogenic agents like alcohol, retinoic acid etc.

Suggested Literature:

1. Developmental Biology, Gilbert, (8th Ed., 2006) Sinauer Associates Inc., Massachusetts, USA.
 2. Principles of Development, Wolpert, Beddington, Brockes, Jessell, Lawrence, Meyerowitz, (3rd Ed., 2006), Oxford University Press, New Delhi, INDIA.
 3. Analysis of Biological Development, Kalthoff, (2nd Ed., 2000), McGraw-Hill Science, New Delhi, INDIA.
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ZOOL 201: Developmental Biology

Practicals

1. Study of life cycle of *Drosophila melanogaster*.
 2. Study of embryogenesis in *Drosophila* and pattern of gene expression in embryogenesis by *in situ* hybridization technique.
 3. Immunohistochemical staining to study the expression pattern of gap and pair-rule gene proteins.
 4. Dissection and study of larval and prepupal wing, leg and eye antennal imaginal discs of *Drosophila*.
 5. Patterning of the adult wing and demonstration of the effect of cell death on the patterning of the adult wing.
 6. Study of Homeotic gene mutations.
 7. Influence of temperature and teratogenes on animal development.
 8. Study of regeneration in *Hydra*.
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ZOOL 202: Systematics, Biodiversity and Evolution

Theory

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

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 archaea; diversification of genomes; the nature of bacterial and archaeal genomes; origin of genomes by horizontal gene transfer; role of plasmid, transposons, integrons and genomic islands in DNA transfer.

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.

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.

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 Hallgrímsson, 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

ZOOL 202: Systematics, Biodiversity and Evolution

Practicals

1. Isolation of Genomic DNA from a bacterium and its quantification.
 2. Designing primers for 16S rRNA gene sequence.
 3. Amplification of 16S rRNA gene sequences by using genomic DNA as well as by colony boiling method.
 4. Purification of 16S rRNA gene.
 5. Sequence of 16S rRNA gene; editing the sequence, multiple alignments, construction of phylogenetic trees and interpretation of results.
 6. Dot blot hybridization of different eubacterial species and interpretation of results.
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ZOOL 203: Immunology

Theory

Overview of the immune system: components of the immune system, principles of innate and adaptive immunity, the recognition and effector mechanisms of the adaptive immunity- antigen and immunogenicity, clonal selection theory.

Antigen recognition by immune cells: Adaptive immunity- antibody structure, antigen recognition by B lymphocytes, TCR, antigen recognition by T- cells, co- receptors, structure and function of MHC complex; generation of lymphocyte antigen receptors- generation of diversity in immunoglobulins, T- cell receptor gene rearrangement, structural variations in immunoglobulin constant regions; antigen processing and presentation to T lymphocytes- antigen presenting cells, generation of T- cell receptor ligand, and MHC restriction, role of CD1 in antigen presentation; Innate Immunity- pattern recognition in the innate immune system, role of TLRs in innate immune response, complement and innate immunity, induced innate response to infection.

Effector mechanisms and regulation of immune responses: Signaling through immune system receptors- antigen receptor structure and signaling pathways, other signaling pathways that contribute to lymphocyte behavior; development and survival of lymphocytes- B lymphocyte development and survival, humoral immune response, T lymphocyte development and survival, production of effector T- cells, cytotoxic T- cell effector mechanisms; NK and NKT cell functions; mucosal immunity; immunological memory; regulation of immune response: cytokines and chemokines, complement system, leukocyte activation and migration, APC regulation of the immune response, T- cell mediated regulation of immune response, Immunological tolerance and anergy.

Immunity in health and disease: introduction to infectious disease, innate immunity to infection, adaptive immunity to infection, evasion of the immune response by pathogens; immunodeficiency diseases- inherited immunodeficiency diseases, acquired immune deficiency syndrome; allergy and hypersensitivity- IgE and allergic reactions, hypersensitivity diseases; autoimmunity- responses to self antigens, transplant rejection- responses to alloantigens; manipulation of immune responses, vaccines; evolution of immune system- evolution of innate immune system, evolution of adaptive immune system.

Suggested Literature:

1. Kuby Immunology, Richard, Thomas, Barbara, Janis, (5th Ed., 2003), W. H. Freeman and company, New York, USA.

2. Immuno Biology- The immune system in health and disease, Janeway, Travers, Walport and Shlomchik, (6th Ed., 2005), Garland Science Publishing, New York, USA.
3. Immunology, David, Brostoff and Roitt, (7th Ed., 2006), Mosby & Elsevier Publishing, Canada, USA.

ZOOL 203: Immunology

Practicals

1. Dissection of primary and secondary immune organs from mice:
 - a. Preparation of single cell suspension from bone marrow and spleen (spleenocytes) of mice.
 - b. Cell counting and viability testing of the spleenocytes prepared.
 2. Preparation and study of phagocytosis by splenic/peritoneal macrophages.
 3. Raising polyclonal antibody in mice, serum collection and estimating antibody titre in serum by following methods:
 - a. Ouchterlony (double diffusion) assay for Antigen -antibody specificity and titre.
 - b. ELISA
 4. Antibody purification from the serum collected from immunized mice: affinity purification/chromatography.
 5. Immunoelectrophoresis.
 6. Demonstration of Western blotting:
 - a. Protein estimation by Lowry's method /Bradford's method
 - b. SDS-PAGE.
 - c. Immunoblot analysis.
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ZOOL 204: Molecular Cell Biology

Theory

Transport - recapitulation of the plasma membrane; mechanism of diffusion, facilitated diffusion, active transport with suitable examples; movement of water; Donnan equilibrium; 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; molecular mechanism of the secretory pathway; secretion of neurotransmitters.

Cellular shape, motility and energetics- cytoskeletal elements in cell shape and motility: structure and dynamics; role in cell locomotion and mitosis; Intercellular communication: extracellular matrix; cell- cell and cell-matrix adhesion; gap junctions; cellular energetics: oxidation of glucose and fatty acids; the proton motive force; F_0F_1 ATP synthase; mechanism and regulation of ATP synthesis.

Life cycle of a cell - cell cycle and its regulation; checkpoints in the mammalian cell cycle; tumor suppressors and role of helicases; regulation of cell proliferation and differentiation by hormones, neuropeptides and growth factors; cell differentiation; apoptosis; turnover of cellular components: targeting of proteins to lysosomes for degradation; degradation of cytosolic proteins; cells in culture: requirements for cell culture; aseptic technique; primary culture; cell lines; organotypic cultures; cytotoxicity assays.

Cell regulatory mechanisms- regulatory and control mechanisms in a mammalian cell at the biochemical level; key concepts about cellular signaling mechanisms: proliferative, survival and death pathways; G- protein coupled receptors; receptor tyrosine kinases; MAP kinase cascade; second messenger systems; desensitization of receptors; signaling and toxins; Signaling pathways in malignant transformation of cells; cell transformation: role of oncogenes. siRNA and miRNA basics, regulation of transcription and translation of proteins by miRNA.

Suggested Literature:

1. Molecular Cell Biology, Lodish *et. al.*, (2007), W.H. Freeman and Company, New York, USA
2. Molecular Biology of the Cell, Alberts *et. al.*, (2008), Garland Science, Taylor & Francis Group, New York, USA.
3. Cell Physiology Source Book : A Molecular approach, Sperelakis, (2001), Academic Press, New York, USA.

ZOOL 204: Molecular Cell Biology

Practicals

1. Sub cellular fractionation of functional mitochondria
 - a. Isolation of mitochondria from mouse liver by differential centrifugation.
 - b. Determination of protein yield in the fractions by Lowry method.
 - c. Identification of mitochondrial fraction by assay of marker enzyme.
 2. Microtubules in vesicle transport in fish chromatophores.
 3. Mammalian cell culture
 4. Assessment of proliferation in cultured cells by MTT assay.
 5. Over-expression and affinity purification of SH3-GST recombinant protein from bacterial cells.
 6. Demonstration of protein-protein interaction between recombinant SH3-GST fusion protein and ovarian proteins by SDS-PAGE
 7. Effect of protein synthesis/ DNA synthesis inhibitor on cell responses to a hormone.
 8. Observation of DNA fragmentation in apoptotic cells.
 9. Glut mediated transport of glucose across the plasma membrane in mammalian cells.
 10. Electrophoretic mobility shift assay (EMSA) for Protein-DNA interactions.
 11. Introduction to FACS analysis.
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ZOOL 301: Principles of Ecology

Theory

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.

Nature of ecosystem, production, food webs, energy flow through ecosystem, biogeochemical cycles, resilience of ecosystem, ecosystem management. The biosphere, biomes and impact of climate on biomes.

Environmental Stresses and their management, global climatic pattern, global warming, atmospheric ozone, acid and nitrogen deposition, coping with climatic variations. 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.

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.

Suggested Literature:

1. Field Sampling: Principles and Practices in Environmental Analysis, Conklin, A.R. Jr., (2004), CRC Press.
2. Principles and Standards for Measuring Primary Production, Fahey, T.J. and Knapp, A.K., (2007), Oxford University Press, UK
3. Ecological Modeling, Grant, W.E. and Swannack, T.M., (2008), Blackwell.
4. Fundamental Processes in Ecology: An Earth system Approach, Wilkinson, D.M., (2007), Oxford University Press, UK

ZOOL 301: Principles of Ecology

Practicals

Habitat studies:

1. Physical and chemical characteristics of soil.
2. Assessing influence of light, temperature and moisture on plant germination and growth/animal behavior and growth.
3. Assessing influence of soil nutrient status on plant germination and growth.

Community/ecosystem studies:

1. Assessment of density, frequency and abundance of plants/animal in a community using various techniques i.e. transect, quadrat etc.
2. Comparison of stands/communities and ordination.
3. Profile diagrams.
4. Biomass and reproductive allocation under various environments.
5. Nutrient uptake and budget for various communities/Food chain assessment.
6. Decomposition of various organic matters and nutrient release mechanisms/role of arthropods and other micro-, and macrofauna in decomposition.
7. Understanding ecosystem succession by studying various stages of vegetation/community assemblages development.
8. Molecular techniques in laboratory.
9. Insect diversity in soil.

Landscape studies:

1. Principles of GIS, GPS and RS technology.
 2. Interpretation (visual and automated) of remote sensing information for landscape differentiation.
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ZOOL 302: Computational Biology, Biostatistics and Bioinformatics

Theory

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 etc; Introduction to Power Point, image and data handling.

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 way and two- way analysis of variance.

The era of computerized biology information, review of relevant definitions in molecular biology, overview of challenges of molecular biology computing, proteins, secondary structure and folding, RNA secondary structures, introduction to phylogenetic analysis; introduction to bioinformatics; introduction to genomics and proteomics databases- nucleic acid sequence database: 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, genes, primer designing; Protein modeling, protein structure analysis, docking, ligplot interactions, phylogenetic analysis with the program PHYLIP, DISTANCES, GROWTREE etc.; introduction to computational genomics and proteomics- basics of

designing a microarray, image analysis and normalization, annotations, protein prediction tools- protein secondary structure, molecular modeling, identification and characterization of protein mass fingerprint, world- wide biological databases, Introduction to programming languages such as “C”.

Suggested Literature:

1. Principles of Biostatistics, Pagano M., Gauvreau, K, (2000), Duxbury Press, USA
 2. Bioinformatics for Dummies, Claverie J. M., Notredame C., (2nd Ed., 2007), Wiley Publishing, Inc., New York, USA
 3. Bioinformatics: Sequence and Genome Analysis, Mount, D. W. (2nd Ed., 2001), Cold Spring Harbor Laboratory Press, New York, USA
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ZOOL 302: Computational Biology, Biostatistics and Bioinformatics

Practicals

1. Use of excel sheet for data processing.
 2. Use of search engines like Scopus, Science direct for reference material collection and management.
 3. Nucleic acid and protein sequence databases.
 4. Data mining for sequence analysis.
 5. Web– based tools for sequence searches and homology screening.
 6. Primer designing for gene amplification and gene cloning.
 7. Annotations: ORF finder, Use of ARTEMIS or any other suitable software.
 8. Construction of phylogenetic trees for DNA and proteins.
 9. Introduction to microarray technology.
 10. Identification of peptide finger print by nano LC- MS/MS and database search using MASCOT and OMSSA.
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ZOOL 303: Biology of Parasitism

Theory

Introduction to parasitology; animal associations and host – parasite relationship; distribution of diseases and Zoonosis caused by animal parasites; morphology, life-cycle, mode of infection of *Plasmodium*, molecular biology of *Plasmodium* – drug targets, mechanism of drug resistance, vaccine strategies and proteomic approaches; morphology, life-cycle, mode of infection of *Leishmania*, molecular biology of *Leishmania* – drug targets, drug resistance and vaccine strategies.

Morphology, biology, life-cycle, mode of infection of *Entamoeba*, morphology, biology, life-cycles, mode of infection of *Giardia*; gastro-intestinal nematodes, morphology, biology, life-cycles, modes of entry of *Schistosoma*, *Wuchereria*, *Brugia*, *Ancylostoma*, *Trichinella* and *Dracanculus*; molecular biology of nematodes, vaccine strategies.

Immune response and self-defense mechanisms, immune evasion and biochemical adaptations of parasites; parasites of veterinary importance.

Parasites of insects and their significance; nematode parasites of plants, morphology, biology, lifecycle and infection of crop plants by plant parasitic nematodes, plant parasitic nematodes, host parasite interactions.

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.

ZOOL 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.
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ZOOL 304: Chronobiology

Theory

Milestones in clock research; Chronobiology in 21st century; Evolution of biological timing system; Clocks, genes and evolution; Adaptive functional significance of biological clocks. Studying biological clocks; Biological Rhythms - Ultradian, Tidal/ Lunar, Circadian and Circannual rhythms; Temperature effects and compensation; Perception of natural zeitgeber signals; Geophysical environment - Seasons; proximate and ultimate factors.

Entrainment, masking and zeitgeber cycles; parametric and non-parametric entrainment; Entrainment models; Phase shift, Phase response curves (PRC) and phase transition curves (PTC); Organization of circadian system in multicellular animals; Concept of central and peripheral clock system; Circadian pacemaker system in invertebrates with particular reference to *Drosophila*; Circadian pacemaker system in vertebrates with particular reference to rodents; Suprachiasmatic nucleus (SCN) as the main vertebrate clock; concept of core and shell.

Diversity and complexity of the clock system; Melatonin: Input or output signal of the clock system; Molecular Biology of the circadian pacemaker system: Experiments in the generation of models for the feedback loop comprising the clock, Pre-molecular genetics era, Generic core circadian feedback loop; Molecular clockworks in *Cyanobacteria*, *Neurospora*, *Drosophila* and mammals; Cellular and molecular bases of Entrainment.

Photoreception and photo-transduction; The physiological clock and measurement of day length; Role of photic and non-photoc cues in seasonality; Reversal of roles of principal and supplementary cues; Evolution of photoperiodism: comparative studies; Circannual rhythms and seasonality; Molecular bases of seasonality; The relevance of biological clocks for human welfare - Clock function (dysfunction); Human health and diseases - Chronopharmacology, chronomedicine, chronotherapy.

Suggested Literature:

1. Chronobiology Biological Timekeeping: Jay. C. Dunlap, Jennifer. J. Loros, Patricia J. DeCoursey (ed). 2004, Sinauer Associates, Inc. Publishers, Sunderland, MA, USA
2. Insect Clocks D.S. Saunders, C.G.H. Steel, X. afopoulou (ed.) R.D. Lewis. (3rd Ed) 2002 Barenz and Noble Inc. New York, USA
3. Biological Rhythms: Vinod Kumar (ed 2002) Narosa Publishing House, Delhi/ Springer-Verlag, Germany.

ZOOL 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 (T_b) of human.
 7. Experiments demonstrating the photoperiodic clock.
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ZOOL 305: Proteins- Structure, Functions and Evolution

Theory

Chemical foundation of biology- concepts of pH, pKa, buffer, acidity and basicity, reaction kinetics and mechanism, affinity, equilibrium, natural products and their physiological and pharmacological importance; types of macromolecules and their general properties, proteins as mediators of all physiological and behavioural processes, proteins as inter-cellular communication signals and signal recognition mediators, chemical properties of proteins, structural organization of proteins and its importance for biological functions, separation techniques and protein science, genetic origin of protein sequences, co- and post translational modifications of proteins, protein ligand interactions.

Enzyme catalysis and allosterism, structure-function relationships in antibodies, proton pumps, ion channels and membrane receptors, structural motifs and functional domains proteins-biosynthesis, storage, secretion and circulatory half-life, protein degradation and intracellular lifespan.

Extracellular matrix proteins and proteoglycans, glycoproteins and glycobiology, super molecular assemblies involving proteins (multi- enzyme complexes), nucleic acids (chromatin) and lipids (chylomicrons).

Protein data bases, protein functions and structural domains, convergent and divergent evolution of protein structure and functions; protein engineering, protein denaturation and folding, genetic disorders affecting functional proteins, protein pathology and prions; immobilized enzymes and enzyme technology.

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
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ZOOL 305: Proteins-Structure, Functions and Evolution

Practicals

1. Estimation of protein by the methods of Biuret, Lowry, Bradford and Eosine- a comparison.
 2. Determination of N-terminal amino acid by the Sanger's reagent (FDNB).
 3. Peptide mapping by 2-D electrophoresis.
 4. Paper chromatographic separation of aminoacids.
 5. Estimation of helix content in proteins.
 6. Chemical modification of Tyrosine, Arginine and Cysteine in proteins.
 7. Determination of molecular mass of proteins by SDS-PAGE.
 8. Deamidation of protein in alkaline medium and measurement of released ammonia.
 9. Ligand binding to protein and determination of Kd value.
 10. Kinetic analysis of L-glutamate dehydrogenase activity by UV-spectrophotometer.
 11. Crystallization of a protein.
 12. Estimation of tryptophan content by spectrophotometry.
 13. Protein Kinase action and estimation of phospho serine content.
 14. Biosynthesis of protein-metabolic labeling by radiolabelled amino acid.
 15. Microheterogeneity in proteins-separation of charge isoforms by ion-exchange chromatography.
 16. Measurement of any one hydrodynamic property of a protein.
 17. Bioinformatic analysis of protein sequences.
 18. Protein unfolding analysis by fluorescence measurements on tryptophan.
 19. Solution NMR analysis of a tripeptide.
 20. Quantitative precipitin test and estimation of number of antigenic epitopes.
 21. Immobilization of an active protein- a study.
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ZOOL 306: Structure and Function of Genes

Theory

Structure of nucleic acids- structure of nucleic acids, folding motifs, conformation flexibilities, denaturation, renaturation, kinetics of hybridization, super-coiling of DNA, packaging of DNA in the nucleus, structure of chromatin, chromatin territories. Genetic material and its evolution- structure and function relationships, evolution of genetic material, genes and genomes.

DNA replication, recombination and repair- energetics of nucleic acid polymerization, accuracy during flow of genetic information, DNA polymerases, proof-reading activity, errors and damage in the DNA, mechanism of DNA repair; genome instability; 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.

Post-transcriptional gene control and nuclear transport- types of introns and their splicing, evolution of introns, catalytic RNA, alternative splicing and proteome diversity, regulation of Pre-mRNA Processing, micro RNA and other non-coding RNAs, degradation of RNA.

Transport across the nuclear envelope and stability of RNA- structure of nuclear membrane and nuclear pore complexes, processes of nuclear import and export and their regulation, degradation of RNA. Translational machinery and translational control - energetics of amino acid polymerization, tRNAs and their modifications, aminoacyl tRNA synthetases, accuracy during aminoacylation of tRNA, regulation of initiation of translation in eukaryotes, elongation and its control, inhibitors of translations.

Suggested Literature:

1. Molecular Biology of the Gene, Watson *et al.*, (5th Ed. 2004), Pearson Education, Delhi, INDIA
2. Genes IX, Lewin, (9TH Edition 2008), Jones and Bartlett Publishers, Boston, USA

ZOOL 306: Structure and Function of Genes

Practicals

1. Studies on structure of Gene

- a. Familiarization with sterile-handling techniques for growth of bacteria, such as sterilization, growth media, types of culture etc.
- b. Isolations of genomic DNA from bacteria and mouse/rat liver.
- c. Measurement of absorption-spectrum of DNA, RNA, and nucleotides.
- d. Studies on denaturation of DNA and determination of T_m and calculation of G:C content.
- e. Studies on stability of DNA and RNA towards alkali.

2 Studies on regulation of gene-expression in bacteria

- a. Studies on growth curve of *E.coli* in synthetic medium and calculation of log-phase for metabolic experiments.
- b. Studies on induction of *lac*-operon.
- c. Studies on catabolite repression of *lac*-operon and role of cAMP.

3. Generation and selection of mutants for *lac*-operon, calculation of mutation-frequency.

ZOOL 307: Animal Behaviour

Theory

Introduction - definition, historical out line, patterns of behaviour, objectives of behaviour, mechanism of behaviour, asking questions. Reflexes- reflex action, types of reflexes, reflex arch, characteristics of reflexes and complex behaviour. Orientation primary and secondary orientation; kinesis – orthokinesis, klinokinesis; taxis – different kinds of taxis; sun-compass orientation, dorsal- light reaction.

Eusociality, social organization in honey bee, polyphenism and its neural control, flower recognition, displacement and translocation experiment, various type of communications, production of new queen and hive, swarming, honey bee as super organism. Fixed action pattern: mechanism, deprivation experiment, controversies. FAP- characteristics and evolutionary features. Learning and instincts: conditioning, habituation, sensitization, reasoning.

Innate releasing mechanisms: key stimuli, stimulus filtering, supernormal stimuli, open and closed IRM, mimetic releaser, code breakers. Homeostasis and behaviour: motivational system, physiological basis of motivation, control of hunger drive in blow fly and thirst drive in goat, role of hormone, motivational conflict and decision making, displacement activity, models of motivation, measuring motivation. Hormones and pheromones influencing behaviour of animals.

Altruism – reciprocal altruism, group selection, kin selection and inclusive fitness, cooperation, alarm call. Parental care, parental manipulation, evolutionarily stable strategy, cost benefit analysis of parental care with suitable case studies. Sexual selection: intra sexual selection (male rivalry), inter-sexual selection (female choice), infanticide, sperm competition, mate guarding, sexual selection in human, consequences of mate choice for female fitness, monogamous verses polygamous sexual conflict.

Suggested Literature:

1. Mechanism of Animal Behaviour, Peter Marler and J. Hamilton; John Wiley & Sons, USA
2. Animal Behaviour, David McFarland, Pitman Publishing Limited, London, UK
3. Animal Behaviour, John Alcock, Sinauer Associate Inc., USA
4. Perspective on Animal Behaviour, Goodenough, McGuire and Wallace, John Wiley & Sons, USA
5. Exploring Animal Behaviour, Paul W. Sherman & John Alcock, Sinauer Associate Inc. ,Massachusetts, USA
6. An Introduction to Animal Behaviour, A. Manning and M.S Dawkins, Cambridge University Press, UK

ZOOL 307: Animal Behaviour

Practicals

1. To study the responses of woodlice to hygrostimuli.
 2. To study the geotaxis behaviour of earthworm.
 3. To study the orientational responses of 1st instar noctuid larvae to photo stimuli.
 4. To study the median threshold concentration of sucrose solution in eliciting feeding responses of housefly.
 5. To study the orientational responses of larvae to volatile and visual stimuli.
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ZOOL 308: Comparative Endocrine Physiology

Theory

Concept of endocrinology: introduction to the endocrine system, classes of hormones, modes of hormone secretion. Phylogeny of endocrine system. Endocrine control of various physiological mechanisms in nemerteans, annelids, mollusks, arthropods (Insects and crustaceans) and echinodermates.

Comparative aspects of endocrine physiology in vertebrates. Evolution of pituitary gland; Physiological actions of pituitary hormones. Urophysis and action of its hormone(s). 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, physiological actions of adrenal medullary hormones; Importance of adrenocortical and adrenomedullary interaction.

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 of vitamin D₃; benthic organisms and source of vitamin D; hormonal regulation of calcium and phosphate homeostasis.

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; hormones, vitellogenesis and the evolution of viviparity.

Suggested literature:

1. Comparative Vertebrate Endocrinology, Bentley, P. J., Cambridge University Press, UK
2. Vertebrate Endocrinology, Norris D. O., Elsevier Academic Press,
3. Hand Book of Physiology, American Physiological Society, Oxford University Press, Section 7: Multiple volumes set.
4. The Insects: Structure and Function, Chapman, F.R., The English Language Book Society (ELBS) and The English Universities Press Ltd.
5. The Principles of Insect Physiology Wigglesworth, V. B., ELBS and Chapman and Hall.

ZOOL 308: Comparative Endocrine Physiology

Practicals

1. Dissection 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., *Spodoptera litura*).
 3. Dissection of endocrine system in crustaceans (neurohaemal organ).
 4. Annelids (Earthworm brain/CNS) and mollusks (Brain/Optic glands in *Octopus*).
 5. Pituitary cytology: a comparative study following histology, histochemistry and immunocytochemistry.
 6. Adrenalectomy in rat.
 7. Effect of adrenalectomy on glycogen assay.
 8. Effect of metyrapone and saline administration on adrenal cortex following light microscopy.
 9. Thyroidectomy in rats.
 10. Effect of thyroidectomy and thyroid hormone replacement therapy on ecdysis and testicular functions in reptiles.
 11. Steroid and thyroid hormone assay by ELISA.
 12. Calcium estimation following fluorometry in PTH/Calcitriol treated rats.
 13. Effect of orexigenic and anorexigenic hormones on feeding behaviour of rats.
 14. Induction of vitellogenesis in a seasonally breeding non-mammalian vertebrate.
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Stream 1: -Entomology

ZOOL 4101: Insect Diversity, Society and Evolution

Theory

Morphology: external features and their articulation. Comparative study of head-antennae, mouth parts; thorax – legs, wings; abdominal appendages, genitalia. Taxonomy- historical development of classification of insect, basis of insect classification; classification of insects up to sub orders and up to super families in economical important groups; fossil history, origin and evolution of insects

Insect Society: group of social insects and their social life; evolution of sociality; social organization and social behaviour in honey bee, ants, termites and wasps. Insect Plant Interaction - 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. Forensic Entomology: Introduction, forensically important insects, collection of data from cadaver site, interpretation of data for predicting time and cause of death.

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., Harward Univ. Press, UK
5. Host Selection by Phytophagous insects, Bernays, E. A., and Chapman, R. F., Chapman and Hall, New York, USA
6. Insect Plant Biology, Schoonhoven, L. M., van Loop, J. A., & Dicke. M. Pub. Oxford Univ. Press. USA

ZOOL 4101 - Insect Diversity, Society and Evolution

Practicals

1. Morphology:

- a. Study of head and its sclerites of *Dysdercus*, honeybee, grasshopper and cockroach.
- b. Mounting and display of mouth parts of *Dysdercus*, housefly, honeybee, mosquito and butterfly.
- c. Wings and their venation. Different types of antennae and legs of insects.
- d. Mounting of stinging apparatus of honey bee.

2. Taxonomy:

- a. Identification of insects up to super families.
- b. Collection, preservation and identification of insects. Field studies of insects.

3. Social Insects:

- a. Morphological and anatomical studies of various castes of *Polistes*, *Apis*, *Camponotus*, and *Odontotermes*.
 - b. Collection of various types of social insects and their nests. Sting apparatus of honey bee.
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ZOOL 4102: Insect Physiology, Toxicology & Vector Biology

Theory

Structure and physiology of integumentary, digestive, excretory, circulatory, respiratory, endocrine, reproductive, and nervous system. Sensory receptors. Growth, metamorphosis and diapause in insect.

Definition of pesticides, brief history, pesticides registration, pesticide industries and markets. Dose-response relationship; mode of action of insecticide, carcinogenic, mutagenic and teratogenic effects, and evaluation of toxicity. Group characteristics of insecticide, structure and function of organochlorine, organophosphorus, carbamate, pyrethroid, other plant origin as well as bio-insecticides, neonicotinoids and nitrogenous insecticides, fumigants, IGRs. Metabolism or degradation of pesticides - phase I and phase II reactions. Insecticide resistance and health hazards.

Introduction to vector biology, economic importance and control of fleas, lice, bugs, mosquitoes, flies and parasitoids. Vector-parasite interaction; host-pathogen interaction, Insect transmitting bacteria and viruses of medical, veterinary and agricultural importance; control of insect vector.

Suggested Literature:

1. The Insects: Structure and function, Chapman, R. F., Cambridge University Press, UK
2. Physiological system in Insects, Klowden, M. J., Academic Press, USA
3. The Insects, An outline of Entomology, Gullan, P. J. , and Cranston, P. S., Wiley Blackwell, UK
4. Insect Physiology and Biochemistry, Nation, J. L., CRC Press, USA
5. Toxicology and Risk Assessment: A Comprehensive Introduction, Greim H., and Snyder, R. (ed), John Wiley and Sons, UK
6. The Complete Book of pesticide management, Whitford, F., Wiley Interscience, John Wiley and Sons, UK
7. Safer Insecticides, Hodgson, E., and Kuhr, R. J., (ed), Marcel Dekker Inc., New York, USA
8. Pesticide Application Methods, Matthews, G. A., Blackwell Science, London, UK
9. Pesticide Biochemistry and Physiology, Wilkinson, C. F., Plenum Press, New York, UK
10. Metabolic pathways of agrochemicals Part II, Roberts, T. R., and Hutson, D. H. The Royal Society of Chemistry, UK
11. Medical and Veterinary Entomology Mullen, G. , Durden, L., Academic Press, USA
12. Medical and Veterinary Entomology, Kettle, D. S., Cabi Press, USA
13. Medical Entomology for students, Service, M. Cambridge University Press, UK

ZOOL 4102: Insect Physiology, Toxicology & Vector Biology

Practicals

1. Physiology:

- a. Dissection of alimentary canal of *Dysdercus*, honeybee, butterfly and grasshopper.
- b. Filter chamber of homopteran; salivary glands of mosquito, honeybee and *Dysdercus*.
- c. Excretory system detection of uric acid in malpighian tubules, uptake of dye in malpighian tubules.
- d. Circulation: haemocyte count, estimation of protein in hemolymph.
- e. Respiratory system: dissection of butterfly, *Dysdercus* and grasshopper.
- f. Nervous system: dissection of *Dysdercus*, butterfly, honey bee and locust, stomodeal nervous system of cockroach and grasshopper.

2. Insect Toxicology:

- a. Estimation of LD₅₀ and LC₅₀ using insects.
- b. Pesticide residue analysis of contaminated soil, vegetable and water using TLC, GLC and HPLC.
- c. Studies on dissipation of pesticides from soil and half life estimation.
- d. Estimation of uncertainty and variability in pesticide residue analysis.
- e. Estimation of acetylcholinesterase activity to evaluate the toxicity of xenobiotic compounds.

3. Vector Biology:

- a. Study of life history stages of medically important arthropods, diptera, anoplura, siphonoptera.
- b. Identification and anatomical studies of major vector species of *Anopheles*, *Culex* and *Aedes*.
- c. Field collection of immature stages of mosquitoes. Study of few available pathogens of arthropod-borne diseases.

ZOOL 4103: Pest Ecology & Agricultural Entomology

Theory

Pest - definition and its ecology, pest status, features responsible for evolutionary success of insect species, 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.

Population dynamics of pests - agro-ecosystem, phases of population fluctuation, models of population growth, factors for population fluctuation, population size and regulatory mechanisms.

Identification, seasonal history, biology, 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. Locust- different species and phases, phase transition, periodicity, migration, biology and control measures

Integrated Pest Management: history, different phases of pest control, Quarantine, Physical, Cultural, Chemical, Biological control and, genetic and biotechnological methods of control. Pheromones- production, and their use in pest surveillance and management

Plant resistance to insects: types of resistance, mechanism of resistance-antibiosis, antixenosis, tolerance, factors mediating resistance, JH Mimics & MH-agonist. Transgenic plants: history, *Bacillus thuringiensis* and its mode of action on insect, different subspecies of *Bt*, development of *Bt* plant by recombinant DNA technology, resistance management of *Bt* crop, prospective and controversies of *Bt* crop.

Suggested Literature:

1. Ecology of insects, Speight, M. R., Hunter, M. D., & Watt, A. D., Wiley-Blackwell, UK
2. Insect Plant Biology, Schoonhoven, L. M., van Loon, J.A., & Dicke, M., Publisher Oxford University Press, USA
3. Interrelationship between insects and Plants, Jolivet, P., CRC Press, USA
4. Chemical Ecology of Insects, Carde, R. T., and Bell, W. J., Chapman & Hall, New York, USA
5. Entomology & Pest Management, Pedigo, L. P., Prentice Hall, New Jersey, USA
6. Concepts of IPM, Norris, Caswell-Chen and Kogan, Prentice-Hall, USA
7. Agricultural insects pests of the tropics and their control, Hill, D. S., Cambridge University Press, UK

ZOOL 4103: Insect Ecology and Agricultural Entomology

Practicals

1. Collection and identification of economically important insects and various stages of their life history.
 2. Methods of rearing insects in the laboratory.
 3. Identification of important insect pests of different crop plants and stored products.
 4. Visits to agricultural fields and forests for on spot study of pests and damage caused by them.
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Stream 2: Fish Biology

ZOOL 4201: Evolution and Functional Anatomy of Fish

Theory

Origin, diversity and distribution- origin and evolution of major groups of fishes, evolutionary strategies and morphological innovations, gene and genome duplication, evolutionary genetics, biogeographical distribution, methods employed in phylogenetic studies and fish identification, fish barcoding. Fish as a research model. Body form, swimming mechanisms and buoyancy regulation- propulsive systems, hydrodynamic analyses, swimming modes, fish biomodelling, bioenergetics, strategies for buoyancy regulation. Gas exchange, internal transport and homeostasis- aquatic and aerial respiration, cardiovascular physiology, hematology, fish leucocytes, phagocytes, lymphoid organs, gas transport, osmoionic regulation, acid- base balance, nitrogen excretion and metabolism. Sensory systems- photoreception, chemoreception, mechanoreception, electroreception. Adaptations to environmental extremes- temperature, pressure, stressors. 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, growth. Defense mechanism- integument and Immune system, 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. Reproduction- reproductive strategies, environmental and endocrine factors regulating reproductive cycles, hormonal and molecular mechanisms of oogenesis, spermatogenesis, oocyte maturation and spermiation, fertilization, mechanism of sex determination, maternal factors in early development. Endocrines- piscine endocrine glands, hormones and their role in appetite, osmoregulation, calcium metabolism, cardiovascular regulation and behaviour, hormone receptors in fish, endocrine disruption, behaviour and cognition -patterns of migration, orientation and homing, schooling, feeding, background adaptations, parental care.

Suggested Literature:

1. Biology of Fishes, Bone, Q. and Moore, R., Talyor and Francis Group, CRC Press, U.K.
2. The Physiology of Fishes, Evans, D. H. and Claiborne, J. D., Taylor and Francis Group, CRC Press, UK
3. The Senses of Fish Adaptations for the Reception of Natural Stimuli, von der Emde, R., Mogdans, J. and Kapoor, B. G., Narosa Publishing House, New Delhi, INDIA

ZOOL 4201: Evolution and Functional Anatomy of Fish

Practicals

1. Phylogenetic analysis of bony fish: morphological analysis; mtDNA polymorphisms; comparison of protein sequences and construction of phylogenetic tree.
 2. Display of visceral organs; preparation of fish skeleton; alizarine preparation.
 3. Collection of body fluids (blood sampling; urine collection; gamete collection).
 4. Study of various hematological parameters. Fish immune system – isolation of phagocytes and phagocytosis.
 5. Comparative study of digestive enzymes of herbivore, carnivore and omnivore fishes;
 6. Estimation of apparent digestibility coefficient of consumed food by fish.
 7. Oxygen consumption in relation to body size/stress/anesthesia.
 8. Extraction, isolation and characterization of plasma vitellogenin and egg-yolk proteins.
 9. Gametogenesis and *in vitro* meiotic oocyte maturation.
 10. Primary cell and tissue culture; chromosome preparation.
 11. Surgical procedures (effect of hypophysectomy on osmoregulatory parameters; effect of gonadectomy on fish)
 12. Chromatophore responses to surgical and chemical procedures.
 13. Visit to a fish market in Delhi, identification of dominant finfish and documentation of shellfish.
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ZOOL 4202: Aquatic Resources and Their Conservation

Theory

Riverine fisheries- important river systems and their hydrological conditions, flora and fauna with special reference to fisheries, dams and their impact on riverine fisheries, fish ladders, interlinking of rivers and likely impact on fisheries. Cold water fisheries - ecology of hill streams, biology of important cold water fishes of India, recreational fishing. Lacustrine fisheries - origin of lakes and lake morphology, light, temperature and density relationship in the lacustrine ecosystems, heat energy and water movements, oxygen and other dissolved gases in lakes, pH and redox potential, fisheries profile and potential of major Indian lakes. Estuarine fisheries- major estuarine systems of India, hydrography, flora and fauna with special reference to fisheries. Marine fisheries – coastal and deep sea fisheries, permanent and seasonal stratification, upwelling, the photic zone, control of primary production by light and nutrients availability, chemical properties of sea water, biology of important fishes (sardine, mackerel, tuna), marine protected areas. Integrated resources- coastal wet lands, mangroves, coral reefs, sea grasses and their conservation. Fishing techniques-- technologies for localizing catches-- remote sensing, sonar, radar; crafts and gears. Stock assessment and management-- Natural markers- morphological analyses, environmental signals, genetic analyses; Applied markers- marking and tagging, Stock identification data analysis - stock composition analysis, age and growth, fecundity estimation, application of statistical methods in fisheries. Fish conservation- fishing laws and regulation, permitting. Post harvest technology-- Fish spoilage, rigor mortis, rancidity, enzymatic spoilage, microbial spoilage; Fish preservation and processing- handling of fish at harvest/onboard, principles of fish preservations, methods of preservation, problems associated with fish preservations, quality control, fishery by-products. Aquatic pollution- types and sources, impact of pollution on aquatic organisms, ecosystem analysis- bio-indicators, biomonitoring, environmental factors and fish health, xenobiotics. Waste management- national and international standards. Extension services - basic principles and emerging issues of extension, role of information and communication technology in fisheries extension.

Suggested Literature:

1. Computers in Fisheries Research, Megrey, B. A. and Moksness, E. (2009), Springer, USA
2. Biological Invasions in Marine Ecosystems Ecological, Management and Geographic Perspectives. Rilov, G. and Jeffrey, A. C. (2009), Springer-Verlag, GERMANY
3. Handbook of Fisheries and Aquaculture, Indian Council of Agricultural Research, ICAR, (2006), DIPA, New Delhi, INDIA

ZOOL 4202: Aquatic Resources and Their Conservation

Practicals

1. Identification of Indian common fish faunal resources from cold water, warm water, brackish water, marine water and ornamental fishes.
 2. Physico- chemical parameters of freshwater bodies.
 3. Biological analysis of water and estimation of primary productivity.
 4. Collection of phytoplankton and zooplankton from natural resources and their identification.
 5. Study of benthic macroinvertebrates in natural water bodies.
 6. Study of fishing gears and nets with the help of models.
 7. Simulated experiments on population enumeration.
 8. Salinity tolerance in select fishes.
 9. Determination of age and growth; gonadosomatic index.
 10. Length-weight relationship and condition factor determination.
 11. Experiments on chemoreception using different attractants and repellents.
 12. Toxicity testing with zooplankton/fish.
 13. Visit to a coastal/ mariculture farm and study the socio-economic status of the fisherman community.
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ZOOL 4203: Aquaculture

Theory

Culture technology– freshwater (carps, catfishes, murrels, prawns), brackish water (asian sea-bass, milk fish, mullets, crabs, shrimps), mariculture (mussels, oysters, sea weeds), fish food organisms (algae; *Artemia*; zooplankton). Water Quality Requirements for Aquaculture- Role of temperature, pH, salinity, dissolved oxygen, ammonia, nitrite, nitrate, phosphate, Biological oxygen demand, Chemical oxygen demand. Integrated farming - fish-cum-live stock farming, paddy-cum-fish farming, aquaculture engineering- aquahouse, hatchery, ponds, race ways, recirculating system, cage, pen. Fish seed technology - natural collection, bundh breeding, induced breeding, cryopreservation of gametes. Transport of finfish and shellfish- transport of eggs, fry, fingerlings and adults. Nutrition of aquatic animals - nutritional requirements of commercially important finfish and shellfish, dietary requirements of larvae and brooders, feed types, manufacture and ingredients, anit- nutritional factors in fish feed ingredients and their treatments, use of attractants and growth stimulants in fish feeds, alternative protein sources in aquaculture diets, feeding techniques, role of probiotics in nutrition. Setting up of display aquarium- freshwater and marine aquaria, selection of compatible species, breeding of aquarium fishes. Role of genetics in aquaculture– gynogenesis, androgenesis, triploidy, tetraploidy, hybridization, sex reversal and breeding, production of transgenic fish, impact of GMOs on aquatic biodiversity. Fish health- infection and diseases in fish, common fish pathogens, routes of pathogen entry in fish, methods of colonization and spread of pathogens, immune - evasion mechanisms of fish pathogens. Environmental impact of aquaculture- aquacultural wastes and future developments in waste minimization, environmental consequences of hypernutrification. Fish vaccines- strategy and use in aquaculture.

Suggested Literature:

1. Fishponds in Farming Systems, 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, Pillay, T. V. R., Blackwell Publishing, USA
 3. Aquaculture and Fisheries Biotechnology Genetic Approaches, Dunham, R. A., CABI Publishing, USA
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ZOOL 4203: Aquaculture

Practicals

1. Estimation of hydrobiological parameters- temperature, pH, conductivity, salinity, dissolved oxygen, primary productivity, ammonia, nitrite, nitrate, phosphate, biological oxygen demand, chemical oxygen demand of nursery, rearing, stocking and breeding ponds.
 2. Estimation of ovarian egg counts.
 3. Culture of live food organisms and assay of nutritional quality of live food; estimation of population density of live food organisms.
 4. Decapsulation and hatching of *Artemia* cysts for use in hatcheries.
 5. Demonstration of breeding pools and hatcheries.
 6. Induced breeding of Indian major carps and catfishes.
 7. Identification of eggs, spawn, fry and fingerlings of cultivable fishes of India.
 8. Collection and identification of aquatic weeds and aquatic insects.
 9. Study of feeding habits of fishes by gut content analysis.
 10. Isolation and estimation of fish immunoglobulins; Molecular techniques in fish health management.
 11. Aquarium design and maintenance.
 12. Formulation and preparation of artificial fish food for Indian major carps and Prawns.
 13. Analysis of proximate composition of fish and processed products.
 14. Visit to freshwater/ marine fish farm.
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Stream 3: Genomics, Metagenomics and Epigenetics

ZOOL 4301: Genomics

Theory

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

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.

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

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.

Suggested Literature:

1. Principle of Genome Analysis and Genomics, Primrose, S. B. and Twyman R. M., (7th Ed., 2006), Blackwell Publishing Company, Malden, USA
2. Genomes 3, Brown, T. A., Garland Science Publishing, London, UK
3. Bioinformatics: Sequence and Genome Analysis, Mount, D. W., Cold Spring Harbor Laboratory Press, New York, USA

ZOOL 4301: Genomics

Practicals

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*
 7. Transformation of recombinant plasmid
 8. Induction of cloned gene with IPTG and analysis on SDS-PAGE.
 9. In vitro packaging of lambda DNA, transfection and plaque formation.
 10. Southern hybridization of genomic DNA with suitable gene as probe.
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ZOOL 4302: Metagenomics

Theory

Introduction - from genomics to metagenomics, history of the culture divide, 16S rRNA analysis and culturing, culture independent insight, why genomics is not enough, global impact of metagenomics; next generation of DNA sequencing technologies and potential challenges, the developments and impact of 454 and Solexa sequencing.

Approaches to metagenomics analysis - 16S rRNA based survey, 16S rRNA – microarray (phylochip), sequence base analysis, functional based analysis, heterologous expression, identifying active clones - clone screens, selection and functional anchors, identifying habitats and collecting metadata, gene expression system, single cell analysis; data management and bioinformatics challenges of metagenomics - genomics data, metagenomics data, the importance of metadata, databases for metagenomics data, software, analysis of metagenomics sequence data.

Pioneering projects in metagenomics - the acid mine drainage project, the Sargasso sea metagenomics survey and community profiling, the soil-resistome project, the human-micro biome project, viral metagenomics, large scale sequencing of mammoth DNA; metagenomics of gut: insects, mouse and human beings.

Ecological inference from metagenomics - symbiosis, competition and communication; the metagenomics of soil and soil health; microbial community - genomics in ocean; application of metagenomics - technical advancement in the field, application and expected benefits from large scale metagenomics data, application in human health, agriculture, industry and environment remediation.

Suggested Literature:

1. The New Science of Metagenomics: Revealing the secrets of our microbial planet, Academic press, Washington DC, USA
2. Metagenomics: Sequence from the Environment, NCBI
3. Next generation DNA sequencing, Nature Publishing Group, (Vol. 26 No.10 , Oct,2008)

ZOOL 4302: Metagenomics

Practicals

1. Isolation of Metagenomic DNA from soil samples.
 2. PCR Amplification of 16S rRNA gene sequences from the metagenome.
 3. Construction of phylogenetic trees and estimation of diversity.
 4. Cloning of 16S rRNA genes sequences in *pUC 18* or any other suitable vector.
 5. Conformation of the insert by restriction digestion.
 6. 16S rRNA gene sequence analysis of the clones and estimation of unculturable diversity.
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ZOOL 4303: Epigenetics and Chromatin Biology

Theory

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; intra-nuclear spatial organization of chromatin: MARs and SARs and their importance

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*, position effect variegation, heterochromatin formation, and gene silencing in *Drosophila*, fungal models for epigenetic research: *Schizosaccharomyces pombe* and *Neurospora crassa*; epigenetics of ciliates; RNAi and heterochromatin assembly, role of noncoding RNAs; epigenetic regulation in plants.

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 regulation of the X chromosomes in *C.elegans*, dosage compensation in *Drosophila*, dosage compensation in mammals; types mechanism of chromatin remodeling.

Epigenetics and genome imprinting - DNA methylation in mammals, genomic imprinting in mammals, germ line and pluripotent stemcells, epigenetic control of lymphopoiesis, nuclear transplantation and the reprogramming of the genome. epigenetics and human disease, epigenetic determinants of cancer.

Suggested Literature:

1. Epigenetics, C. David Allis and Thomas Jenuwein, (2007) Cold Spring Harbor Laboratory Press, New York, USA
2. Molecular Biology of Gene, Watson et al., (5th Ed. 2004), Pearson Education, Delhi, INDIA

ZOOL 4303: Epigenetics and Chromatin Biology

Practicals

1. Isolation of nuclei (as a source for studies on structure of chromatin) from rat/mouse liver by discontinuous sucrose-density gradient centrifugation.
 2. Isolation of total histones, and resolution on SDS-PAGE.
 3. Studies on modifications of histones (such as acetylation, methylation etc.) by western-blotting using modification-specific antibodies.
 4. Expression and purification of recombinant histones.
 5. Isolation and characterization of total nuclear proteins.
 6. Digestion of nuclei by MNase and calculation of 'repeat-length' of nucleosomes.
 7. Digestion of nuclei by DNase-I, and studies of DNA superhelicity in the nucleosomes.
 8. Preparation and characterization of soluble-chromatin (10 and 30 nm chromatin-fibers).
 9. Purification of and characterization of mononucleosomes
 10. Reconstitution of nucleosome-core and PCR-amplified synthetic DNA.
 11. Chromatin-immunoprecipitation (ChIP).
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Stream 4: Molecular Endocrinology and Reproduction

ZOOL 4401: Neuroendocrinology

General organization of neuroendocrine organs and nervous system. Neuroanatomy: form, varieties and distribution of neurons; Structural characteristics of neurons; Stereotaxic atlas of rat brain and the hypothalamus. Neurophysiology: electrical properties of neurons and propagation of nerve impulses; Synapse: types, structure and function. Neurotransmitter and its release; Neuromodulation: neurotransmitter vs neuropeptides, Synaptic transmission: role of G-protein coupled, glutamate and on-channel linked receptors; GABA/glutamate neurons in adult preoptic area: sexual dimorphism and function.

The hypothalamo- hypophyseal axis. Hypothalamo- vascular system. Hormones from hypothalamus: chemistry and physiology of releasing and release inhibiting hormones; Regulation of hypothalamic hormone secretion. Hypothalamo- hypophyseal interactions with the gonads, adrenal and other endocrine organs. Diversity of ovarian steroid signaling in the hypothalamus. Development and cytology of pituitary gland. Regulation of pituitary hormone secretion. Neurohypophysis: synthesis and storage of oxytocin and vasopressin; Regulation of the release of neurohypophyseal hormones. Concepts of feed-back inhibition and feed-forward activation.

Regulation of the expression of POMC-related peptides and their differential expression in brain and pituitary. Environment and reproduction. Endocrine disruptors; Embryonic diapause and other adaptive mechanisms. Biological clock and the pineal: synthesis and regulation of melatonin, phylogeny of pinealocytes, role of pineal in circadian rhythms, regulation of pineal by SCN and vice versa, physiological actions of melatonin, biological clock and clock gene expression, fluoride and pineal.

Neuroendocrine regulation of immune system; Stress hormones and immune responses; Regulation of systemic homeostasis by nervous and immune system interactions. Melatonin, immune responses and cancer therapy. Neuroendocrine disorders: genetic versus environmental cause. Principles and application of techniques: electrophysiology, immunocytochemistry, *in situ* hybridization, autoradiography, in vitro perfusion

Suggested Literature:

1. An Introduction to Neuroendocrinology, Brown R., (1994), Cambridge University Press, Cambridge, UK
2. Psychoneuroimmunology, , Ader R, Felten D.L. and edited by Nicholas C. (4th Ed., 2007), Academic Press, UK

3. Endocrinology (3 volumes set), *DeGroot* L. J. and Jameson J.L., Editors, (5th Ed., 2006), Saunders Elsevier Press, USA.
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ZOOL 4401: Neuroendocrinology

Practicals

1. Identification of hypothalamic nuclei following histological, histochemical and immunocytochemical methods.
 2. Stereotaxic atlas of Hypothalamus.
 3. Isolation and characterization of pituitary cells.
 4. LH-RH assay/bio-assay.
 5. Pituitary sensitivity to LHRH.
 6. Stereotaxic devices and administration of stimulants.
 7. Isolation of poly A-RNA from brain tissue.
 8. Designing of primers for molecular cloning.
 9. Effect of litter size on serum prolactin levels in lactating rats.
 10. Tail-flick assay in mice and effect of endorphins.
 11. Effect of restraint stress on phagocyte functions.
 12. *In vitro* effect of glucocorticoid and catecholamines on phagocyte functions.
 13. Effect of chemical pinealectomy and melatonin replacement therapy on phagocyte functions.
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ZOOL 4402: Molecular Endocrinology

Theory

Discovery of hormones as chemical signals for control and regulation of physiological processes. Nature of hormonal actions. Major questions in biology of hormones. Techniques for quantitation of hormones. Design and development of hormonal assays.

Structure of peptide and protein hormones. Purification and characterization of hormones. Structure-Function relationships in different hormones. Phylogenic analysis of hormonal structures and functions. Biosynthesis of protein hormones. Storage and secretion of hormones: molecular mechanisms of regulation. Transcriptional and post-transcriptional mechanisms of hormone biosynthesis and secretion. Regulation of biosynthesis and secretion. Inhibitors of hormone biosynthesis and their use.

Nature of hormonal effects and actions. Discovery of receptors in target tissues. Mechanisms of hormone action and signal attenuation.. Signal discrimination, signal transduction and signal amplification in hormone regulated physiological processes. Structural requirements for successful hormone-receptor interactions. Receptor antagonists and their applications. Metabolism of hormones by target and non-target tissues. Pharmacokinetics of hormones. Hormones and behavior- cellular and molecular actions of semiochemicals.

Hormones as therapeutic agents. Current developments in design and production of hormonal contraceptives. Recombinant protein hormones-production and application in regulation of fertility in farm animals and humans. Evolution of chemical communication in animal systems. Unsolved problems in hormonal biology.

Suggested Literature:

1. Peer reviewed journal articles, monographs and reviews as and when recommended.
 2. Molecular Biology of Steroid and Nuclear Hormone receptors, ed. Freedman L. P., (1998), Birkhauser, Boston, USA
 3. Biochemical actions of hormones, ed. Litwack, G. (1985), Academic press, New York, USA
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ZOOL 4402: Molecular Endocrinology

Practicals

1. Isolation of protein hormone and demonstration of bio- activity in an in vivo bio-assay (e.g. FSH).
2. Immunocytochemical localization of a pituitary hormone using light or electron microscopy (e.g. Prolactin).
3. In vivo bio- assay for estrogen.
4. In vivo bio- assay for testosterone.
5. In vivo bio- assay for luteinizing hormone.
6. In vitro biochemical assay for a hormone (LH or PRL).
7. Effect of hCG on poly A rich RNA content in ovary.
8. Quantitation of specific transcript (mRNA) after ovarian stimulation by hCG or FSH.
9. Affinity purification of ovine/bubaline pituitary TSH.
10. Preparation and characterization of hormone- enzyme conjugate.
11. ELISA for any one hormone and estimation of plasma level.
12. Estimation of cAMP in a rat tissue (e.g. adipose) with and without hormone stimulation.
13. Streptozotocin administered rat model for diabetes.
14. Demonstration of phospholipase C action.
15. Molecular cloning of a protein hormone (e.g. buffalo prolactin).
16. Expression of recombinant buffalo prolactin in E.coli.

ZOOL 4403: Biology of Reproduction

Theory

Sex determination and differentiation: Mechanism of Sex determination, differentiation of gonad and the genital tract.

Stem cell renewal in testis, Spermatogenesis: structural and molecular events, experimental approaches to study spermatogenesis; Seminiferous epithelial cycle; Sertoli cell: structure and function; Leydig cell: generation of Leydig cell, steroidogenesis; Leydig and Sertoli cell proliferation during foetal and postnatal development; Regulation of testicular functions.

Epididymal maturation of spermatozoa; Capacitation, Signal transduction pathway in acrosome reaction; Male sterility: azoospermia, oligozoospermia, asthenozoospermia, varicocele; Genetic basis for male infertility, Mutational analysis in genes for hormones, receptor and gamete development.

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: amenorrhea, polycystic ovary.

Fertilization: A comparative account on pre-fertilization events in oviparous animals (echinoderms-amphibians-mammals), activation of egg, candidate molecules involved in fertilization; Contraception leading to prevention of polyspermy: surgical, hormonal and immunocontraception.

Suggested literature:

1. The Physiology of Reproduction, Vol 1 and 2, Ernst Knobil and Jimmy D. Neil, (ed), Raven Press.
2. Male Reproductive Function, Christina Wang, (ed), Kluwer Academic Publishers.
3. The ovary, (ed), Solly Zuckerman Zuckerman, Barbara J. Weir, T. G. Baker. Academic Press.
4. The ovary, Peter C.K. Leung and Eli Y. Adashi, (ed), Elsevier (Academic Press), 2004.
5. Cell and Molecular Biology of Testis, (ed), Claude Desjardins and Larry L. Ewing. Oxford University Press, USA

6. Reproductive Endocrinology: Physiology, Pathophysiology, and Clinical Management, Samuel S. C. Yen, Robert B. Jaffe, Robert L. Barbieri, (ed), Saunders publisher. USA

ZOOL 4403: Biology of Reproduction

Practicals

1. 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.
 2. Gonadectomy and sex steroids replacement therapy to see the effect on accessory sex organs of rats.
 3. Isolation of testicular cells and ovarian follicular cells.
 4. In vitro experiments with different testicular cells to provide the direct evidence related to humoral and cellular control of testicular functions.
 5. Vaginal smear preparation.
 6. Induction of superovulation and oocyte retrieval from oviduct of immature rat/mouse.
 7. Sperms count and motility: Role of epididymal proteins, mono- and di-valent cations and pH in control of sperm motility.
 8. Capacitation and acrosome reaction under experimental conditions.
 9. Surgical sterilization of male and female rats.
 10. Pseudopregnancy and delayed implantation in adult lactating rats.
 11. Isolation of various stages of germ cells following flow cytometry, Analysis of DNA content in germ cell population.
 12. SDS-PAGE analysis of placental proteins.
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