AC Item No.

UNIVERSITY OF MUMBAI

Program: M.Sc.

Course: Zoology

Syllabus for Semester I & II

(Choice Based Credit System
with effect from the academic year 2019-20)

Syllabus Committee

Coordinator – Dr. Supriya K. Deshpande

Semester I
Paper I: Non-chordates
Convener: Dr. Manisha Kulkarni
Members: Prof. Dr. Rahul Jadhav, Dr. Utkarsha Chavan, Dr. Shital Taware

Paper II: Developmental Biology I
Convener: Dr. Roshan D'Souza
Members: Dr. Sharad Mahajan, Dr. Vinayak Parab, Ms. Sandhya Kadiru

Paper III: Genetics and Evolution
Convener: Dr. Varsha Andhare
Members: Dr. Surekha Gupta, Dr. Nandita Singh, Dr. Vinda Manjramkar

Paper IV: Frontiers in Zoology
Convener: Dr. Rajendra More
Members: Dr. Pratiksha Savant, Dr. Mangesh Jamble, Dr. S.S. Waghmode

Semester II
Paper I: Chordates
Convener: Dr. Dilip Kakvipure
Members: Dr. Alka Chougule, Dr. Sushant Mane, Dr. Sandip Garg

Paper II: Developmental Biology II
Convener: Dr. Bhavita Chavan
Members: Dr. Dandavate, Dr. Sashibhal Pandey, Dr. Rana Ansariya

Paper III: Biochemistry and Biotechnology
Convener: Dr. Subhash Donde
Members: Dr. Rupinder Kaur, Dr. Rishikesh S. Dalvi, Dr. Gayathri N.

Paper IV: Research Methodology
Convener: Ms. Seema Ajbani
Members: Nitin Wasnik, Dr. Minakshi Gurav, Dr. Devdatta Lad

CONTENTS

1. **Preface**
2. **Preamble**
3. **Pedagogy**
4. **Tables of Courses, Topics, Credits and Workload**
5. **Theory Syllabus for Semester I (Course codes: PSZO101-PSZO104)**
6. **Practical Syllabus for Semester I (Course code: PSZOP101-PSZO104)**
7. **References Course codes: (PSZO101- PSZO104)**
8. **Theory Syllabus for Semester II (Course codes: PSZO201-PSZO204)**
9. **Practical Syllabus for Semester II (Course code: PSZOP201-PSZO204)**
10. **References (Course codes: PSZO201-PSZO204)**
11. **Marking Scheme of Examination (Theory and Practical)**
12. **Skeleton Papers: Semester I and Semester II**

PREFACE

The overall objective of revising the syllabus of Zoology, M.Sc. semester I and II is to offer students the advancements in the different components of the subject. The syllabus is framed and designed to include the recent developments useful for the students to shape their career. The purpose of revision of the syllabus is to upkeep the student with the necessary theory and practical, so that the learner can progress with confidence for his further independent fields into specialized areas such as research.

The syllabus also embraces objectives and desired outcomes which will provide clear idea to the teacher as well as learner about the expected depth of the topic.

The pedagogy supports a self-motivated learner to gain knowledge of the subject and prolong the borders of a classroom. The pedagogy recommends projects, assignments, visits etc. which is an extension to the regular classroom methodologies. It deals with the additional suggestions for bringing the objectives into actual instructional activities. The suggested resources in the reference lists would be useful in achieving the desired outcome. It would also assist an instructor in planning the lectures in a sensible modus beneficial for the learners.

This syllabus was developed by the curriculum committee of 33 dedicated teachers. Their major role was to abridge, grow, augment and give a forward bearing to the Zoology taught in undergraduate curriculum, with projections to future requirements. They have successfully completed the colossal task. I congratulate them.

– Dr. Deelip L. Bharmal
Chairman BOS, Zoology

PREAMBLE

There is a vast ocean of information in various forms in today's world of information technology. Recent research all over the world is incessantly adding and replacing earlier philosophies. To convert the scattered data in to the useful and applicable knowledge of the subject for the learners, we update our syllabus from time to time.

The aim to revise the Zoology M.Sc. semester I and II syllabus is to equip and update our learners with most recent up gradations in the field and to develop useful skills in them to face the challenges of their future career. The present syllabus is prepared to provide most recent topics useful for the postgraduate students, keeping in mind their employability as well. The syllabus will also be expedient for the students aspiring for civil services.

The whole team of thirty two dedicated members of the syllabus committee operated in unison and worked really hard to give out their best for the syllabus after several conventions, discussions, deliberations, explorations and exchange of innovative ideas. I acknowledge their efforts.

There is always a scope for improvement in any work. So I request all stakeholders to give their inputs, valuable suggestions and recommendations to improve the syllabus during further revision.

Coordinator
Dr. Supriya K. Deshpande

PEDAGOGY

PSZO101 is ‘Non-chordates’, a study of Comparative functional anatomy, paleontology and phylogeny as well as all internal structures and various systems of non-chordates like protostomes and deuterostomes. It also assists in understanding of the anatomical similarities and differences of various systems. Practical aspects of functional anatomy and phylogeny could be undertaken through observation of various systems at laboratory level, field visits, constructing phylogenetic tree and making fossil casts.

PSZO102 consists of ‘Developmental biology I’ which explains reproductive biology, molecular biology, genetics and morphology of non-chordates. The basic concepts of the reproductive process – fertilization could be taught considering the mechanism in relation to its molecular aspect. Applications of reproductive biology could be dealt with by taking various examples of economic importance. Practical aspects of developmental biology could be undertaken through observation of life cycles of various organisms that can be cultured in the laboratory as per the ethical permission granted so that learners can understand the theoretical approach in a much better way.

The course PSZO103 ‘Genetics and Evolution’ will help the learner for conceptual understanding of the basic genetic principles along with genetic evolution and the impact it creates at the genome and molecular level with major phenotypic variation. Short basic experiments on drosophila or nematodes or video clips can be shown by the concerned teacher while clearing the concept of the topics. Teachers are expected to show the video clips or fossil photographs for the understanding of the topic. A visit to museum, institute or the archeological site to study fossils can be organised.

The course PSZO104 ‘Frontiers in Zoology’ is prepared to introduce emerging interdisciplinary scientific fields such as Astrobiology and Chronobiology. For understanding of medical imaging techniques visits to medical diagnostic centers should be organized. Teachers are expected to elucidate the scope of medical diagnostic techniques as career options. Guest lectures of the experts could be arranged, who can provide additional insights to these aspects. Documentaries and videos based on climate change and global warming can be effectively used to provide in-depth knowledge to the learners. Case studies could be supplemented to understand the intensity of climatic change and global warming and its impact. The learners can be made aware about emotions, stress and associated health problems through the interaction with clinical psychologist and through videos of experts dealing the subject.

In course PSZO201 ‘Chordates’, an attempt has been made to inform the students the basic comparative, functional morphology and phylogeny of chordates. Learners will be able to acquire the knowledge of evolutionary progression of primitive nonchordate to protochordates. They will also learn basic taxonomy of chordates, the beautiful world of biodiversity and through this they can enter in to the field of nature conservation or strategize to spread knowledge for future generations. This endeavor will be possible by utilizing various teaching methodologies such as use of model, charts and available specimens. This goal will to be achieved by the use of audio visuals, virtual dissections and observation of animals in their natural habitat through field visits.

In course PSZO202 ‘Developmental Biology II’, generalized account of reproductive systems in chordates has been included to provide knowledge of reproductive system .This can be

taught through virtual dissection. It also deals with physiology of reproduction where documentaries and videos can be shown to students for effective learning. Students can be given micro projects for in-depth knowledge or a visit to reproductive research centres could be organized. It can also be taught through case study and guest lectures.

PSZO203 ‘Biochemistry and Biotechnology’ unit comprehends chemical and physicochemical processes which occur within living cell or organisms and utilization of biological processes for industrial and other purposes through the genetic manipulation of microorganisms respectively. The unit can be made more explicable by observing available video clips and visits on open day programs to the institutions like CIFE, NIRRH, ACTREC, KEM etc. The learners can also achieve an additional knowledge on the topic through attending free on- line courses on the https://www.coursera.org

PSZO204 ‘Research methodology’ unit is framed to help the learners build a strong foundation for pursuing research. Visit to relevant websites should be undertaken to make them aware of different avenues for acquiring research grants, scholarships and funding and also to gain valuable insights about various model organisms and their applications in research. Methods of data management and analysis can be explained using different online and offline softwares to enable the learners to acquire these skill sets. The practical should be organized such that learners can be trained to manage large data sets generated via multiple observations, arrange them in a proper format and present them in relevant graphs/charts by adopting a hands-on in silico approach. Visits may be organized to nearby research institutions having CPCSEA certified Animal House and labs housing various model organisms so that students can acquire an in-depth knowledge on these topics. Guest lectures by leading research scientists may also be arranged to enrich the learners and stimulate their interest in forging a career in this field in the future.

– Conveners and committee members

M. Sc. I Zoology Syllabus
Choice Based Credit System
To be implemented from the Academic Year 2019-2020
SEMESTER I

Paper 1: Non-Chordates				
Course Code	**UNIT**	**Topic Headings**	**Credits**	**L/Week**
PSZO101	**1**	Digestion and Excretion	**4**	**1**
	2	Respiration and Circulation		**1**
	3	Nervous System & Chemical Co-ordination and Reproductive System		**1**
	4	Paleontology and Phylogeny		**1**
Paper 2: Developmental Biology I				
Course Code	**UNIT**	**Topic Headings**	**Credits**	**L/Week**
PSZO102	**1**	Fertilization and Early Development in Non-chordates	**4**	**1**
	2	Basic Concepts of Embryonic Development in Non-chordates		**1**
	3	Early Development in Non-chordates		**1**
	4	Special Aspects in Reproduction and Development in Non-chordates		**1**
Paper 3: Genetics and Evolution				
Course Code	**UNIT**	**Topic Headings**	**Credits**	**L/Week**
PSZO103	**1**	Introduction to Evolutionary Genetics	**4**	**1**
	2	Molecular Genetics		**1**
	3	Evolution – Anthropology		**1**
	4	Evolution and Fossils		**1**
Paper 4: Frontiers in Zoology				
Course Code	**UNIT**	**Topic Headings**	**Credits**	**L/Week**
PSZO104	**1**	Astrobiology and Chronobiology	**4**	**1**
	2	Modern Techniques in Medical Field		**1**
	3	Biological Psychology and Neurobiology of Stress and Emotions		**1**
	4	Climate Change and Sustainability		**1**
			16	**16**
Practical				
PSZOP101	Non-Chordates		**2**	**1**
PSZOP102	Developmental Biology I		**2**	**1**
PSZOP103	Genetics and Evolution		**2**	**1**
PSZOP104	Frontiers in Zoology		**2**	**1**

SEMESTER II

Paper 1: Chordates				
Course Code	**UNIT**	**Topic Headings**	**Credits**	**L/Week**
PSZO201	**1**	Protochordates and Agnatha	**4**	**1**
	2	Phylogeny of Chordates		**1**
	3	Functional and Comparative Anatomy of Chordates		**1**
	4	Assorted Topics on Chordates		**1**
Paper 2: Developmental Biology II				
Course Code	**UNIT**	**Topic Headings**	**Credits**	**L/Week**
PSZO202	**1**	Generalized Account of Reproductive Systems in Chordates	**4**	**1**
	2	Physiology of Reproduction		**1**
	3	Developmental Biology- Germ cells, Stem cells and Induced Breeding		**1**
	4	Animal Development – Impact of Environment and Evolution		**1**
Paper 3: Biochemistry and Biotechnology				
Course Code	**UNIT**	**Topic Headings**	**Credits**	**L/Week**
PSZO203	**1**	Fundamentals of Biochemistry	**4**	**1**
	2	Metabolism and Metabolic Pathways		**1**
	3	Processes and Techniques in Biotechnology		**1**
	4	Applications of Biotechnology		**1**
Paper 4: Research Methodology				
Course Code	**UNIT**	**Topic Headings**	**Credits**	**L/Week**
PSZO204	**1**	Principles of Scientific Research	**4**	**1**
	2	Data Management and Analysis		**1**
	3	Scientific Communication		**1**
	4	Model organisms and their applications		**1**
			16	**16**
Practical				
PSZOP201	Chordates		**2**	**1**
PSZOP202	Developmental Biology II		**2**	**1**
PSZOP203	Biochemistry and Biotechnology		**2**	**1**
PSZOP204	Research Methodology		**2**	**1**

M. Sc. Part 1: Semester I (Theory)
Paper 1: PSZO101: Non-Chordates

Unit 1: Digestion and Excretion (15L)

Objectives

- *To understand functional anatomy, differences and similarities of digestive and excretory systems of non-chordates.*

Desired Outcome

- *The learner will be able to differentiate anatomical and physiological modifications of digestive and excretory systems of non-chordates like Protostomes and Deuterostomes.*

1.1 General organization of digestive systems of Protostomes (Annelids, Arthropods and Molluscs) and Deuterostomes (Echinoderms and Hemichordates)

1.2 Digestive Systems with Special emphasis on the organs or glands of :

1.2.1 Annelids

- Clamworm – Denticles or Paragnaths, Jaws

1.2.2 Arthropods

- Prawn: Buccal cavity, Cardiac and Pyloric stomach, Hepatopancreas

1.2.3 Molluscs

- *Pila*: Odontophore, Sub-radular organ, Radula, Oesophageal pouches, Cardiac and Pyloric chambers, Salivary gland, Hepatopancreas

1.2.4 Echinoderms

- Starfish: Cardiac and Pyloric stomach, Intestinal Caeca, Digestive glands

1.2.5 Hemichordates

- Balanoglossus: Buccal Diverticulum, Digestive Pharynx, Post-branchial canal, Hepatic and post-hepatic regions

1.3 General organization of excretory systems of Protostomes (Annelids, Arthropods and Molluscs) and Deuterostomes (Echinoderms and Hemichordates)

1.4 Excretory Systems with Special emphasis on the organs/structures or glands of:

1.4.1 Annelids

- Clamworm: Coiled Nephridia

1.4.2 Arthropods

- Prawn: Antennal glands or Green glands or Maxillary glands, Bladder, Renal sac

1.4.3 Molluscs

- *Pila*: Organ of Bojanus, anterior Renal chamber, posterior Renal chamber

1.4.4 Echinoderms

- Starfish: Water Vascular System, Coelomocytes, Intestinal caeca

1.4.5 Hemichordates

- Balanoglossus: Glomerulus or Proboscis gland

Unit 2: Respiration and Circulation (15L)

Objectives

- *To understand anatomical differences and similarities of respiratory and circulatory systems in non-chordates.*
- *To understand physiological processes in non-chordates.*

Desired Outcome

- *The learner will be able to differentiate anatomical and physiological modification in respiratory and circulatory systems of non-chordates like Protostomes and Deuterostomes.*

2.1 General organization of respiratory systems of Protostomes (Annelids, Arthropods and Molluscs) and Deuterostomes (Echinoderms and Hemichordates)

2.2 Respiratory Systems with Special emphasis on the organs/structures or glands of:

2.2.1 Annelids

- Clamworm: Parapodia, Body wall

2.2.2 Arthropods

- Prawn: Branchiostegites, Branchiae, Epipodite

2.2.3 Molluscs

- *Pila*: Ctenidium, Pulmonary sac

2.2.4 Echinoderms

- Starfish: Dermal papulae, Tube Feet

2.2.5 Hemichordates

- *Balanoglossus*: Gill slits, Branchial sac, Gill pores

2.3 General organization of circulatory systems of Protostomes (Annelids, Arthropods and Molluscs) and Deuterostomes (Echinoderms and Hemichordates)

2.4 Circulatory systems with special emphasis on the organs/ structures or glands of:

2.4.1 Annelids

- Clamworm: Dorsal blood vessel, Ventral blood vessel, Transverse vessels

2.4.2 Arthropods

- Prawn: Heart and Blood lacunae

2.4.3 Molluscs

- Pila: Pericardium, Heart

2.4.4 Echinoderms

- Starfish: Perihaemal sinuses, Axial gland

2.4.5 Hemichordates

- Balanoglossus: Central Sinus (Heart), Dorsal vessel, Ventral vessel

Unit 3: Nervous System, Chemical Co-ordination and Reproductive System (15L)

Objectives

- *To compare nervous systems and chemical co-ordination in non-chordates.*
- *To understand similarities and differences in the reproductive systems of non-chordates.*

Desired Outcome

- *The learner will be able to differentiate anatomical and physiological modifications of nervous systems and chemical co-ordination of non-chordates.*

- *The learner will be able to differentiate modifications of reproductive systems of non-chordates.*

3.1 General organization of Nervous systems& Chemical Co-ordination in Protostomes (Annelids, Arthropods and Molluscs) and Deuterostomes (Echinoderms and Hemichordates)

3.2 Nervous system & Chemical Co-ordination with special emphasis on the organs/structures or glands of:

3.2.1 Annelids

- Clamworm: Corpora pedunculata, Giant fibre, Circumpharyngeal ganglion, Peristomal cirri, Nuchal organ, pigmented Retinal cells

3.2.2 Arthropods

- Prawn: Brain, Circum-oesophageal commissure, Compound eyes, Chromatophore, Statocysts, Tactile setae, Olfactory setae, Tangoreceptors, Chemoreceptors, Proprioreceptors, Sinus gland X organ complex, Y organ

3.2.3 Molluscs

- *Pila*: Cerebral Ganglia, Buccal Ganglia, Pleuro-pedal Ganglionic Mass, Supra-intestinal Ganglion, Visceral Ganglion, Osphradium, Tentacles, Statocysts, Eyes, Mechanoreceptors, Photoreceptores, Temperature receptors, Chemoreceptors

3.2.4 Echinoderms

- Starfish: Ectoneural nervous system, Langer's nerve, Eyes, Terminal tentacles, Neurosecretory cells

3.2.5 Hemichordates

- *Balanoglossus*: Epidermal Plexus, Preoral ciliary organ, Neurosecretory cells

3.3 General organization of reproductive systems in Protostomes (Annelids, Arthropods and Molluscs) and Deuterstomes (Echinoderms and Hemichordates)

3.4 Reproductive systems with special emphasis on the organs/structures or glands in:

3.4.1 Annelids

- Clam worm: Gonads – Testes and Ovaries (Temporary)

3.4.2 Arthropods

- Prawn: Male – Testes, Vasa deferentia, Vasiculae seminalis; Female – Ovaries, Oviducts

3.4.3 Molluscs

- *Pila*: Male – Testes, Vasa efferentia, Vasa deferens, Vasicula seminalis, Hypobranchial glands; Female – Ovary, Oviduct, Receptaculum seminis, Uterus, Vagina, Hypobranchial gland

3.4.4 Echinoderms

- Starfish: Male / Female gonads

3.4.5 Hemichordates

- Balanoglossus: Saccular gonads

Unit 4: Paleontology and Phylogeny (15L)

Objectives

- *To understand evolution of non-chordates by studying their fossils found in Indian sub-continent.*
- *To understand phylogeny of non-chordates.*

Desired Outcome

- *The learner will be able to understand the evolution of non-chordates and their phylogenetic relationships by means of paleontological evidences.*

4.1 Fossils of:

4.1.1 Annelids: *Serpula* and *Glomerula* spp. found in South India

4.1.2 Arthropods: Trilobites found in Kashmir, Insects trapped in amber found in Western India

4.1.3 Molluscs: Molluscs fossils found in Kutchh, Chhattisgarh and Jammu – *Palmerella kutchensis, Cimomia forbesi,* Lamellidens

4.1.4 Echinodermata: *Gongrochanus spp*. found in South India, Echnoid fossils found in India.

4.1.5 Hemichordata: Graptolite fossils

4.2 Phylogenetic affinities of Annelida, Arthropoda, Mollusca, Echinodermata and Hemichordata

4.2.1 Phylogenetic relationships of Trochophore larva

4.2.2 Similarities and differences between Annelids and Molluscs

4.2.3 Phylogeny of Arthropods – Monophyletic theory and polyphyletic theory

4.2.4 Phylogeny of Echinoderms – Asterozoan hypothesis and Cryptosyringid hypothesis

4.2.5 Affinities of Annelida with Hemichordata

4.2.6 Affinities of Echinodermata with Hemichordata

4.3 Construction of Phylogenetic Tree

4.3.1 Genetic distance

4.3.2 Rooting trees

4.4 Phylogenetic Tree Building Methods

4.4.1 Distance-Based Methods:

- UPGMA Method
- Neighbour Joining Method (NJ)
- Weighted Neighbour-Joining (Weighbour)
- Fitch-Margoliash (FM) and Minimum Evolution (ME) Methods

4.4.2 Character-based Methods:

- Maximum parsimony (MP)
- Maximum Likelihood (ML)

Paper 2: PSZO102: Developmental Biology – I

UNIT 1 – Fertilization and Early Development in Non-chordates (15 L)

Objectives

- *To introduce learners to the concept, mechanism and molecular events of fertilization in non-chordates*
- *To introduce the concept of germ layers and coelom formation.*

Desired Outcome

- *The learner will understand the mechanism of fertilization and its molecular events in non-chordates.*
- *The learner will appreciate the process of formation of germ layers and coelom in animals and understand the difference in these processes between Protostomes and Deuterostomes*.

1.1 Concept and Mechanism of Fertilization

1.1.1 Types of reproduction – Asexual and sexual
1.1.2 Fertilization – Concept and types
1.1.3 Mechanism of fertilization
- Capacitation of sperm
- Recognition of sperm and egg
- Acrosome reaction
- Activation of egg
- Fusion of egg and sperm cell membrane
- Amphimixis

1.2 Molecular Events of Fertilization

1.2.1 Species specific recognition of gametes – Fertilizin and antifertilizin interaction, Binding protein
1.2.2 Prevention of polyspermy – Fast and slow block
1.2.3 Calcium as initiator of cortical granule reaction
1.2.4 Activation of egg metabolism with respect to Sea urchin

1.3 Formation of Germ Layers and Coelom Formation

1.3.1 Post Fertilization events: Overall view of Cleavage, Blastulation, Gastrulation
1.3.2 Formation of Germ layers – Diploblastic, Triploblastic
1.3.3 Coelom formation in Protostomes and Deuterostomes

Unit 2: Basic concepts of embryonic development in non-chordates (15L)

Objectives:

- *To introduce basic concepts of embryonic development and embryogenesis.*
- *To understand therapeutic applications of stem cells.*

Desired outcome:

- *Learners would understand basic concepts and aspects of embryogenesis and stem cell therapy.*

2.1 Fate map and cell lineages: potency and commitment

2.2 Competence and induction

2.3 Mosaic and regulative development

2.4 Cell specification:
- **2.4.1** Autonomous specification
- **2.4.2** Conditional specification
- **2.4.3** Syncytial specification

Unit 3: Early Development in non-chordates (15L)

Objectives:

- *To introduce the learners about the process of early development and differences in the pattern of development in non-chordates.*
- *To help learners understand specific gene regulation during development.*

Desired Outcome

- *Learners will understand the mechanism of early development and able to correlate the various differences observed in the pattern of embryonic development in non-chordates.*
- *Learners will understand the role of certain genes in early development*

3.1 Development of *Caenorhabditis elegans*
- **3.1.1** Pattern of cleavage
- **3.1.2** Anterior-posterior axis formation
- **3.1.3** Dorsal-Ventral axis formation
- **3.1.4** Cell specification (Autonomous and Conditional)
- **3.1.5** Process of gastrulation

3.2 Early Development in *Drosophila melanogaster:*
- **3.2.1** Pattern of cleavage
- **3.2.2** Blastulation
- **3.2.3** Process of gastrulation
- **3.2.4** Anterior-posterior pattern formation by morphogenetic protein gradient
- **3.2.5** Dorsal-ventral pattern formation by morphogenetic protein gradient
- **3.2.6** Patterns of homeotic gene expression: *Homeo* selector gene complexes (Hom-C, homeotic gene complex) – Antennapedia and bithorax complexes and their functional domains, Realistor genes: *distal less* and *wingless* genes

Unit 4: Special Aspects in Reproduction and Development in non-chordates (15L)

Objectives:

- *To understand diversities in reproduction and development in non-chordates.*
- *To understand the mechanism of regeneration*
- *To help learners to relate applications of developmental biology with forensics and IPM*

Desired outcome:

- *Learners will acquire knowledge about the diversities in reproduction and development in invertebrates and the process of regeneration in lower animals.*
- *Learners will understand how principles of developmental biology can be applied in forensics and IPM*

4.1 Sexual Reproduction in Protozoa

- Conjugation in *Paramoecium sp*.
- Syngamy in flagellates

4.2 Metagenesis in *Obelia sp.*

4.3 Polyembryony in *Fasciola sp.*

4.4 Regeneration in *Hydra* (Morphallactic) and Planaria (Totipotency)

4.5 Parthenogenesis in Aphids

4.6 Metamorphosis in insects – Indirect Development

4.6.1 Types of insect metamorphosis
4.6.2 Eversion and differentiation of imaginal disc
4.6.3 Hormonal control of insect metamorphosis
4.6.4 Study of life cycle of Blow fly-applications in forensics
4.6.5 Larval forms of non-chordates: Amphiblastula larva (Porifera), Planula (Coelenterata), Echinopluteus (Echinodermata) and Tornaria (Hemichordata)

4.7 Pheromones in invertebrates and their role as sex attractants and in Integrated Pest Management (IPM)

Paper 3: PSZO103: Genetics and Evolution

Unit 1: Introduction to evolutionary genetics: (15L)

Objectives:

- *To develop in learners the understanding of genes, genomes in evolution.*
- *To comprehend the pattern of genetic relatedness between all species.*
- *To understand the contribution of genetic variation in phenotypic expression*

Desired outcome:

- *The learners will understand the genetic analysis at the gene, genome and population level.*
- *The learner would realize the flow of genetic information and complex networking of genes in biological system leading to major phenotypic changes.*

1.1 Cytochrome 'c'

1.1.1 Structure of Cytochrome 'c' and couple cytochrome 'c'
1.1.2 Cytochrome 'c' in eukaryotes. Example Primates
1.1.3 Cox gene
1.1.4 Molecular basis of haemoglobin gene structure. Haemoglobin as a model of evolution

1.2 Sex Determination and Evolution of Sex Chromosome

1.2.1 Theory of evolution of sex chromosome
1.2.2 Evolution of sex chromosomes from autosomes
1.2.3 Biology of Y chromosome
1.2.4 Molecular level of sex determination in mammals
1.2.5 Sex based gene expression
1.2.6 T6sRNA

1.3 Cytoplasmic Inheritance/Extra-nuclear Inheritance

1.3.1 Introduction – human mitochondrial genetics
1.3.2 Paternal and maternal mtDNA inheritance in humans
1.3.3 mtDNA mutations and human diseases
1.3.4 Salient feature of cytoplasmic inheritance

1.4 Selfish Gene

1.4.1 Introduction and definition
1.4.2 Individual altruism and genetic egoism
1.4.3 Green beard effect

Unit 2: Molecular Genetics (15L)

Objectives:

- *To get acquainted with applications of genes in modern science and population genetics.*
- *To give in-depth knowledge of biological processes through molecular mechanisms.*

Desired Outcome:

- *The learner will understand the molecular processes that occur in and between the cells.*

- *The learner will gain insight in most significant molecular and cell based methods used to expand the understanding of modern Biology.*

2.1 Gene Library

2.1.1 Molecular analysis of gene and gene products
2.1.2 Types – Genomic Library, cDNA Library
2.1.3 Construction of genomic library – human antibody gene library
2.1.4 Applications of gene library

2.2 Types of Genes: Definition

- Multigenes
- Repeated genes
- Single copy gene
- House-keeping gene (constitutive gene)
- Luxury gene (non-constitutive gene)
- Pseudogene
- Jumping gene (Transposons)
- Overlapping gene
- Structural gene
- Processed gene
- Split gene
- Regulatory gene

2.2.1 Multi-gene Families and Types:

a) Split Genes or Interrupted genes
   - Introduction
   - Structure of split genes
   - Discovery and theory of split genes
   - Evolution of split genes

b) Pseudogenes
c) Selfish gene

2.2.2 Overlapping Gene

2.3 Mapping units

2.3.1 Types –genetic mapping and physical mapping
2.3.2 Detection of linkages
2.3.3 Construction of linkage maps in diploids and their characteristics
2.3.4 Co-efficient of coincidence
2.3.5 Outline of other types of gene mapping

2.4 Gene cloning

2.4.1 Definition and strategies of gene cloning
2.4.2 Techniques in gene cloning
2.4.3 Applications of gene cloning in DNA analysis in research

2.5 Population genetics

2.5.1 Population genetics in DNA typing
2.5.2 Mutation – Selection balance
2.5.3 Parallelism between random drift and inbreeding

Unit 3: Evolution – Anthropology **(15L)**

Objective:

- *To give an insight to students about the expression, perpetuation and adaptations of animals in varied environment during the process of evolution*

Desired Outcome:

- *Learner will be able to gain knowledge of altruism, co-evolution and the racial distribution of animals in evolutionary time scale*

3.1 Racial distribution of Primates and *Homo sapiens*

3.1.1 Racial distribution of primates
- Distribution of Prosimians (Lemurs, Lorises, Galagos)
- Distribution of Anthropoids (Monkeys and Apes)

3.1.2 Divergence of *Homo sapiens* from Anthropoid

3.2 Racial distribution of *Homo sapiens*

3.2.1 Biological races in humans
- Caucasoid (White) race
- Negroid (Black) race
- Capoid (Bushmen/Hottentots) race
- Mongoloid (Oriental / Amerindian) race
- Australoid (Australian Aborigine and Papuan) race

3.2.2 Human genetic diversity protein-based polymorphism (Blood groups, Alu polymorphism), craniometrics

3.3Importance of Human Genetic Biodiversity

3.3.1 Applications – Anthropological, Medical, Cultural
3.3.2 Parasites and human co-evolution
3.3.3 Ectoparasite's co-evolution with humans (Head Louse, Scabies, Mite)
3.3.4 Endoparasites co-evolution with humans (Liver fluke, Tapeworm, *Ascaris*, Sickle cell Individuals as an example of co-evolution with malarial parasite)

3.4 Altruism and Evolution

3.4.1 Altruism – Intra-species and Interspecies, Cooperation and its evolution in human
3.4.2 Altruism and evolution in domesticated wild animals
3.4.3 Group selection and kin selection
3.4.4 Domestication and behavioral changes

3.5 Hybrid Evolution

3.5.1 Natural Hybrids – Origin and evolution of animal hybrids, Insects, Snails, Fish, Frog, Lizard
3.5.2 Hybrid Speciation
3.5.3 Artificial Hybrids – Hybrid optimization – Bee Colony
3.5.4 Artificial cells in hybrids to create
- Dzo
- Mule
- Hinny

- Liger
- Wholpin
- Leopon
- Zorse

Unit 4: Evolution & Fossils (15L)

Objectives:

- *To help students to solve biological problems that impact our lives and to understand similarities and differences between human and other species with respect to body form, behaviour, adaptation, distribution pattern and physiology.*
- *To understand learner that fossil records provide history of earth as they occur in a particular order.*
- *To impart the learner with knowledge of preserving endangered species by the technique of biomaterial banking, assisted reproductive technology and frozen zoo.*

Desired Outcome:

- *The learner will be able to apply evolutionary principles to research and understand aspects of evolution.*
- *Learner will be acquainted with techniques of dating fossils and formation of fossils.*
- *The learner will understand the concept of frozen zoo and will foster the need of hour for conservation of endangered species.*

4.1 Human evolution

4.1.1 Human evolutionary history and placing humans on tree of life
4.1.2 Genomics and humanness; current issues in human evolution
4.1.3 Brief Accounts of *Parapithecus spp., Propliopithecus spp., Dryopithecus spp., Ramapithecus spp., Australopithecus spp., Kenyanthropus spp., Homo spp.,* Neanderthal, Cromagnon and Modern man
4.1.4 Concept of neutral evolution, molecular divergence and molecular clock

4.2 Fossil dating

4.2.1 Geological timescale – Eras, Periods and Epochs
4.2.2 Major events in evolutionary time scale
4.2.3 Significance of fossils and fossilization
4.2.4 Fossil dating – Types: Absolute and Relative Dating
4.2.5 Process of C-14 Carbon dating

4.3 Frozen zoo

4.3.1 Concept of frozen zoo to save endangered species
4.3.2 Techniques to create offspring from cells of endangered species, nuclear transfer, mixing cells, creating sperms and eggs
4.3.3 Current status of frozen zoo

Paper 4: PSZO104: Frontiers in Zoology

Unit 1: Astrobiology and Chronobiology (15L)

Objectives:

- *To introduce recent interdisciplinary scientific fields to the learners.*
- *To inculcate interest for interdisciplinary research among the learners.*

Desired outcome:

- *Learners will get the introductory knowledge of emerging areas correlated with Zoology.*
- *Learners will understand the different types of biological clocks and their importance.*

1.1 General aspects of Astrobiology, status of research in astrobiology and future perspectives, factors determining habitability on planets; extremophiles

1.2 Bio-signatures of life in exoplanet atmosphere

1.3 Search for life on Mars; search for extra-terrestrial intelligence

1.4 Introduction to Chronobiology – Definition and meaning

1.5 Biological rhythms

1.5.1 Introduction

1.5.2 Types

- Circadian rhythms
- Tidal rhythms
- Lunar rhythms
- Semilunar rhythms
- Circannual rhythms

1.6 Structure of Biological Clock in Insects and Vertebrates; biological clock function

1.7 Relevance of Biological Clocks for Human Welfare

1.7.1 Chronomedicine

1.7.2 Chronotherapy

1.8 Molecular mechanisms controlling the circadian rhythm (Noble Prize winning work, 2017)

Unit 2: Modern Techniques in Medical Field (15L)

Objectives:

- *To provide the basic knowledge of different modern techniques used in medical field.*
- *To provide information of applications of biomedical techniques.*

Desired outcome:

- *Leaner would be able to explain the basic principles, applications of the major imaging and DNA bar coding techniques.*

2.1 Physical aspects of medical imaging

2.1.1 Laser beam in Biology and Medical field
2.1.2 Medical lasers (Carbon Dioxide Laser, Nd: YAG Laser)
2.1.3 Applications of lasers in therapy and diagnosis.

2.2 Principle and applications of major medical imaging techniques

2.2.1 Radiography
2.2.2 Echocardiography (2D and 3D Echo)
2.2.3 Computed Tomography Scan (CT scan)
2.2.4 Magnetic Resonance Imaging (MRI)

2.3 Radioisotope Imaging: Introduction and applications

2.4 DNA bar coding technique and its applications

2.5 Molecular Cytogenetic Techniques and their Applications

2.5.1 Fluorescence *in situ* Hybridization (FISH)
2.5.2 Genomic *in situ* Hybridization (GISH)
2.5.3 Flow cytometry
2.5.4 Automated karyotyping
2.5.5 Chromosome painting

Unit 3: Biological Psychology and Neurobiology of Stress and Emotion (15L)

Objectives:

- *To give learners the basic knowledge of emotions, stress and associated health problems.*
- *To introduce learners to the brain regions that forms the basis of emotions.*

Desired outcome:

- *Learner will get acquainted with brain regions that form the basis of emotions and stress.*
- *Leaner will also understand the health problems caused due to prolong emotion and stress on the body.*

3.1 Introduction and general features of emotions

3.2 Neuronal basis of emotion

3.3 Types of emotions – Definition and management

- Fear
- Frustration
- Joy / Happiness
- Sadness
- Embarrassment
- Guilt
- Shame
- Anger
- Love
- Inspiration

3.4 Measurement of emotions

- Self-report
- Behavioral observations
- Physiological measure

3.5 Role of brain regions in emotions

- Limbic system
- Amygdala
- Cortex
- Hypothalamus
- Midbrain Periaqueductal Grey
- Neurochemicals involved in emotions

3.6 Concept of Stress, Measurement of stress, Characterising stress – Signs of stress, Types of stressors

3.7 Stress and the Hypothalamus-Pituitary-Adrenal Axis (HPA Axis)

3.8 Remedial measures to combat psychological stress and negative emotions

Unit 4: Climate Change and Sustainability (15L)

Objectives:

- *To provide the information about the causes of climatic change.*
- *To make the student aware of various national and international initiatives on climate change.*

Desired outcome:

- *The learner will understand current challenges of climatic changes and environmental issues.*
- *Learner will understand the importance of the sustainable development.*

4.1 Climate change

4.1.1 Introduction
4.1.2 Indicator species of climate change
4.1.3 Vulnerability and adaptations

4.2 Greenhouse effect

4.2.1 Greenhouse gases
4.2.2 Increase in greenhouse gas concentrations
4.2.3 Global warming potential of greenhouse gases

4.3 Intergovernmental Panel on Climate Change [IPCC]: Objectives and functioning

4.4 United Nations Framework Convention on Climate Change (UNFCCC) – Salient Features and Objectives

4.4.1 Kyoto protocol
4.4.2 Doha Amendment
4.4.3 Emission trading / Carbon Trading

4.5 Sustainable development

4.5.1 Introduction and goals

4.5.2 Sustainable habitat – Green building, *Griha* rating norms

4.6 Green Audit – Introduction and Types:

- Energy audit
- Waste disposal audit
- Water audit
- Carbon audit

4.7 Impact of climate change on terrestrial and aquatic organisms

4.8 Case Studies on Climatic Change and Global Warming

- Kerala floods
- Impact of highway and road construction on animal survival
- Impact of urbanization: Dhaka – Bangladesh

M. Sc. Part 1: Semester I Practical 1
PSZOP101: Non-Chordates

1. Study of digestive systems of clamworm, prawn, *Pila*.
2. Study of digestive systems of starfish, Balanoglossus.
3. Study of excretory systems of clamworm, prawn, *Pila*.
4. Study of excretory systems of starfish, *Balanoglossus*.
5. Study of larval forms of Annelids, Arthropods, Molluscs with reference to phylogeny.
6. Study of larval forms of Echinoderms with reference to phylogeny.
7. Study of nervous systems of clamworm, prawn, Pila.
8. Study of nervous systems of starfish and *Balanoglossus*.
9. Study of male reproductive systems of clamworm, prawn, *Pila.*
10. Study of male reproductive systems starfish, *Balanoglossus*.
11. Study of female reproductive systems of clamworm, prawn, *Pila.*
12. Study of female reproductive systems starfish, *Balanoglossus*.
13. A. Study of Fossils:
    a. Annelids: *Serpula and Glomerula spp.*
    b. Arthropods: Trilobites, Insects trapped in amber
    c. Molluscs: *Palmerella kutchensis, Cimomia forbesi,* Lamellidens

    B. Study of Fossils:
    d. Echinodermata: *Gongrochanus spp.*, *Goniocidaris*
    e. Hemichordata: Graptolite fossils
14. Construction of phylogenetic tree.
15. Making of fossil casts with *Shaadu* Clay / Muddy soil*.
16. Field visit to observe invertebrates in their natural habitat and accordingly the modifications of various systems.
17. Field visit to study fossils to the places such as museums, Institutions, quarries, archeological sites etc.

***Note: Plaster of Paris and Plasticine Modelling clay should not be used to make fossil casts.**

Practical 2: PSZOP102: Developmental Biology – I

1. To culture Paramecium to study conjugation and binary fission under the microscope.
2. To observe development of *C. elegans.*
3. To culture *Drosophila* to study its life cycle.
4. To observe stages of *Tribolium* or *Sitophilus* to understand indirect development in animals.
5. To study germ layers:
    - Diploblastic – T.S. of body wall of sponges and cnidarians (coelenterates)
    - Triploblastic acoelomate – T.S. of body wall of Platyhelminthes
    - Triploblastic pesudocoelomate– T.S. of body wall of *Ascaris*
    - Triploblastic coelomate –T. S. of body wall of earthworm
6. To study gemmule in sponge.
7. To study larvae of non-chordates:
    - Porifera – Amhiblastula
    - Cnidaria (Coelenterata) – Planula
    - Annelida and Molluscs– Trochophore
    - Mollusca – Glochidium
    - Crustacea
        - Nauplius
        - Zoea
        - Mysis
        - Megalopa
    - Echinodermata
        - Auricularia
        - Echiopluteus
    - Hemichordata– Tornaria
8. To study Life cycle of Butterfly / Moth (Insecta).

Observation should be done by using Permanent slides/ Photos/Charts/ Preserved specimens/Animal models for studying the developmental aspects.

Practical 3: PSZOP103: Genetics and Evolution

1. To Isolate DNA from the given blood sample.
2. To study the Kappa particles in *Paramecium* cultured in laboratory.
3. To study the maternal effects in Drosophila due to induced environmental changes.
4. To study the Avian brood parasitism in cuckoo, crow, Asian koel, Shiny cowbird.
5. To study Haemoglobin of domesticated dogs, cats, cattles with the help of comparative protein sequence charts using bioinformatics tools.
6. Study of Altrusim, reciprocal altruism in Vampire bat, thumping of ground gene in Rabbit.
7. To study different types of fossils:
   a. Body Fossils – A wall of large dinosaur bones, *Turritella* snail shells from the Miocene age (Photograph)
   b. Mould & casts – Ammonite, Clam shell
   c. Per mineralization or petrifaction fossils – Per mineralized Dinosaur Bone (Photograph), permineralized Fern Stripe (Photograph).
8. To study cloning in India – eg. Garima – Assamese Buffalo, Noori – Pashmina goat.
9. Study of syndromes – Cockeye syndrome (CS), Proteus syndrome, Muenke syndrome.
10. Problems on gene mapping and mitotic index.

Practical 4: PSZOP104: Frontiers in Zoology

1. Identification of photographs with respect to chronobiology.
   a. Structure of biological clock in insects
   b. Structure of biological clock in vertebrates
2. Identification of photographs of different imaging techniques.
3. Determination of concentration of iron as a pollutant from sample / sample solution by – Redox titration or spectrophotometric method.
4. Detection of heavy metals from given sample: a) Zinc b) Lead c) Copper.
5. To estimate the amount of dust (particulate matter) deposition on the leaves of roadside plants.
6. Study of animals as indicators for climate change and global warming
   a. Green turtle
   b. Birds – Sparrow
   c. Polar bear
   d. Coral reef
   e. Butterflies
7. Study of gross anatomical regions of brain involved in stress and emotion.
8. Environment Audit report (Green Audit / Review of EIA of a Selected Area)
9. Visit to nearby bar coding laboratory / imaging center and submission of report.
10. Assignment or report submission on pulse rate after stress.

References PSZO101:

1. Invertebrates – Protozoa to Echinodermata, Author: Ashok Verma, Publisher- Narosa Publishing House.
2. Invertebrate Zoology, Authors: E. L Jordan and P. S. Verma, Publisher: S. Chand and Company Ltd.
3. Invertebrate Zoology 3rd edition, Author: Paul A. Meglitsch and Fredrick R. Schram, Publisher – Oxford University Press.
4. Introduction to General Zoology Vol. I, Author: Korak Kanti Chaki, Gautam Kundu and Supriti Sarkar, New Central Book Agency (P) Ltd.
5. Introduction to General Zoology Vol. II, Author: Korak Kanti Chaki, Gautam Kundu and Supriti Sarkar, New Central Book Agency (P) Ltd.
6. Modern Text Book of Zoology: Invertebrates, Author: R. L. Kotpal.
7. Invertebrate Zoology by N.C Nair, S. Leelavathy, et al.
8. Textbook of Zoology: Invertebrates Vol I 7/e by Haswell.
9. Textbook of Invertebrate Zoology by Dev Bhattacharya.
10. Invertebrates by Richard C. Brusca, Wendy Moore, Stephen M. Shuster.
11. Invertebrate Zoology: A Functional Evolutionary Approach, Authors: Richard Fox, Robert D. Barnes, Edward E. Ruppert.
12. An Introduction to Mollusca by G. S. Sandhu and Harshvardhan Bhaskar, Campus Book International.
13. An Introduction to Echinodermata by G. S. Sandhu and Harshvardhan Bhaskar, Campus Book International.
14. Principles of Invertebrate Paleontology by N. Shrock.
15. Palaeontology Invertebrate by Henry Woods.
16. Phylogenetic Trees Made Easy: A How-to Manual by Barry G. Hall.
17. Invertebrate Zoology by P. S. Dhami and J. K. Dhami.
18. Practical Zoology by K. C. Ghose
19. Practical Zoology – Invertebrate by S. S. Lal.
20. http://www.biologydiscussion.com/zoology/practicals/structure-of-squid-loligo-with-diagram-zoology/60685

References PSZO102:

1. Developmental Biology – Scott F. Gilbert – 8th Edition, Sinauer Associates Inc., 2006
2. Principles of Development – L. Wolpert – 4th Edition, Oxford University Press, 2011.
3. Essential Developmental Biology- J.M.W. Slack – 2nd Edition, Blackwell Publishing, 2006
4. Modern Text Book of Zoology- Invertebrates by R.L .Kotpal, Rastogi Pub,10th Edn, 2013.
5. An Introduction to Embryology by B. I. Balinsky, CBS College Pub, 5th Edn, 1981.
6. Biology of the Invertebrates by Jan A. Pechenik, Tata McGraw- Hill, 4thEdn, 2000.
7. Invertebrate Zoology by P. S. Dhami and J. K. Dhami, R. Chand and Co.3rd Rev.Edn,1974
8. General and Applied Entomology by B. V. David and T. N. Ananthakrishnan, Tata McGraw- Hill, 2thEdn, 2004.
9. Modern Entomology by D. B. Tembhare, Himalaya Publishing House,1st Edn,1997.
10. https://phys.org/news/2014-09-blowfly-maggots-physical-evidence-forensic.html
11. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3296382/
12. https://www.canr.msu.edu/resources/pheromone_traps_the_gypsy_moth_e2585

References PSZO103:

1. Morphology of the primates and human evolution R.P Srivastava.
2. Animal behavior by S. Prasad.

3. Text of Animal Behaviour by H.S Gundevia.
4. Animal behavior Saras publication Kenneth Oakley, Title of book.
5. Fossil in Earth Sciences by Anis kumar Ray.
6. Evolution Donal R. Prothero.
7. Principals of paleontology David M. Raup, Stanley.
8. Fossil Records, John Morris.
9. General genetics by Winchester.
10. Molecular Biology of gene by Watson et al. Vol I & II.
11. Genetics by Strickberger.
12. Molecular Biology by Friefielder.
13. Genetics by P.K. Gupta.
14. Molecular cell biology by Darnell, Lodish and Baltimore (Scientific American books).
15. Evolution by Savage.
16. Process of organic evolution by Stebbings.
17. Evolution of vertebrates by Colbert Concepts of Genetics, 9th edition (2008), William S. Klug, Michael R. Cummings, Charlotte Spencer, and Michael A. Palladino, Publisher-Benjamin Cummings.
18. Genes IX, 9th edition (2008), Benjamin Lewin, Publisher-Jones and Barlett Publishers Inc.
19. Principles of Genetics, 4th edition, (2006), Snustad D. Peter and Simmons J. Micheal, Publisher -John Wiley and Sons. Inc.
20. Genetics, (1999), Daniel J. Fairbanks, W. Ralph Andersen Publisher- Brooks/Cole Pub Co.
21. Principles of Genetics, 8th edition (1991), Eldon J. Gardner, D.P. Snustad, M.J. Simmons, and D. Peter Snustad Publisher-John Wiley and Sons. Inc.
22. Microbial Genetics, (1987), David Freifelder, Publisher-Jones & Bartlett.
23. General Genetics, (1985), Leon A. Snyder, David Freifelder, Daniel L. Hartl Publisher-Jones and Bartlett.
24. Genetics, 3rd edition, Monroe W. Strickberger, (1968), Publisher – Macmillan Publishing Co.

References PSZO104:

1. Animal Behaviour (Ethology) by Dr. V. K. Agarwal, S. Chand and Company Ltd. New Delhi.
2. Chronobiology Biological Timekeeping: Jay. C. Dunlap, Jennifer. J. Loros, Patricia J. De Coursey (ed). 2004, Sinauer Associates, Inc. Publishers, Sunderland, MA, USA.
3. Insect Clocks, by D.S. Saunders, C.G.H. Steel, X., afopoulou (ed.) R.D. Lewis. (3rd Ed) 2002 Barens and Noble Inc. New York, USA.
4. Biological Rhythms: Vinod Kumar (ed.2002) Narosa Publishing House, Delhi/ Springer-Verlag, Germany.
5. Molecular mechanisms controlling the circadian rhythm by Michael Rosbash, Michael W. Young & Jeffrey C. Hall, (Nobel Prize winner 2017).
6. Principles and techniques of practical biochemistry Ed. B. L. Williams and amp; K. Wilson, Arnold Publishers.
7. Medical Imaging Physics by W. R. Hendee, E.R. Ritenour, Wiley-Liss, 2002.
8. An Introduction to The Principles of Medical Imaging, Guy, D. ffytche, Imperial College Press, 2008.
9. Medical Instrumentation applications and design by John G. Webster.
10. Biomedical Instrumentation Technology and applications by Khandpur. McGraw – Hill.
11. Biomedical Instrumentation systems by Shakti Chatterjee.

12. Hand Book of Bio-Medical Instrumentation by R. S. Khandpur, McGraw Hill Publishing Co. Ltd. 2003.
13. Biomedical Instrumentation and Measurements Leslie Cromwell, Fred J. Weibell, Erich A. Pfeiffer, Pearson Education.
14. Bio-Medical Instrumentation by M. Arumugam, Anuradha Agencies
15. Lasers and Optical Fibers in Medicine by Katzir A.: Academic Press, Inc. 1993.
16. Techniques in life science by Tembhare.
17. Biological Psychology 3rd edition, by Frederick Toates, Prentice Hall, Pearson Education Limited.
18. Biological Psychology,10th Edition, James V. Kalat, North Carolina State University, 2009, 2007 Wadsworth, Cengage Learning.
19. Introduction to Psychology, 9th edition, James Kalat North Carolina State University, Wadsworth, Cengage Learning.
20. Neurobiology – Gorden M. Sheperd.
21. Principles of Neural Science – E. Kandel and others.
22. Essentials of Neural Science and Behaviour – E. Kandel and others.
23. Elements of Molecular Neurobiology – C U M Smith.
24. Fundamentals of Ecology and Environment, Second edition by Pranav Kumar and Usha Mina, Pathfinder Publication New Delhi, India.
25. Elements of Ecology by Smith TM and Smith RL (2009), 7th ed. San Francisco CA: Pearson Benjamin Cummings.
26. Concepts of Ecology by Kormondy E.J. (1996), 4th ed. W.H. Prentice-Hall.
27. Ecology: Global insights and investigations by Stiling P (2015), 2nd ed. McGraw-Hill Education.
28. Environmental Science Laboratory Manual For Senior Secondary Course, National Institute Of Open Schooling A-24/25, Institutional Area, Sector-62, Noida-201309 (U.P.)

M. Sc. Part 1: Semester II (Theory)
Paper 1: PSZO201: Chordates

Unit 1: Protochordates and Agnatha **(15L)**

Objectives:

- *To equip learners with the knowledge of evolutionary progression of Protochordates.*
- *To familiarize learner with the origin, morphology and phylogeny of the Protochordates.*

Desired outcome:

- *Learners would be equipped with the understanding of morphology and phylogeny of Protochordates.*

1.1 Protochordates

1.1.1 Origin and ancestry of Protochordates, similarities and differences with Invertebrates and Chordates

1.1.2 Comparison of characteristics between subphyla Urochordates and Cephalochordates

1.2 Urochordates

1.2.1 Life history of *Herdmania* and its phylogenetic affinities

1.3 Cephalochordates

1.3.1 General features and phylogenetic affinities

1.3.2 Life history of *Branchiostoma*

1.4 Ostracoderm

1.4.1 Salient features and biological significance

1.4.2 Interrelationship and affinities with fish

1.5 Cyclostomes

1.5.1 Resemblance with Cephalochordates, Vertebrates and differences from Fishes

1.5.2 Life history of *Petromyzon*

Unit 2: Phylogeny of Chordates **(15L)**

Objectives:

- *To provide learners with the knowledge of evolutionary progression of Protochordates.*
- *To familiarize learner with the origin, morphology and phylogeny of the Protochordates.*

Desired outcome:

- *Learners would be equipped with the understanding of morphology and phylogeny of Protochordates.*

2.1 Ancestry of Chordates

2.2 Pisces

2.2.1 General characters of Dipnoi and affinities with Fishes, Elasmobranchs and Amphibia

2.2.2 Origin of air bladder and its relationship with tetrapod lungs
2.2.3 Deep sea adaptations of fishes
2.2.4 Origin of fins

2.3 Amphibia
2.3.1 Origin of Tetrapods
2.3.2 Pedomorphosis
2.3.3 Adaptive radiation in amphibians Lepospondyli and Lissamphibia

2.4 Reptilia
2.4.1 Origin of Reptiles and affinities with Amphibia
2.4.2 Terrestrial adaptations in Reptiles

2.5 Aves
2.5.1 Origin of Birds and affinities with Reptiles
2.5.2 Adaptive radiation in Birds – Ratitae (Flightless Birds) and Carinatae (Flying Birds)
2.5.3 Origin of Flight – Theory of Cursorial and Arboreal origin

2.6 Mammalia
2.6.1 Origin of Mammals
2.6.2 Phylogeny of terrestrial and aquatic mammals

Unit 3: Functional and Comparative Anatomy of Chordates (15L)
Objectives:
- *To equip learners with the knowledge of evolutionary progression of chordates.*
- *To familiarize learner with the origin, morphology and phylogeny of the chordates.*

Desired outcome:
- *Learners would understand evolution, morphology and phylogeny of chordates.*

3.1 Comparative Anatomy of:
3.1.1 Chondrocranium
3.1.2 Splanchnocranium
3.1.3 Skull in different Vertebrates

3.2 Evolution and Comparative Anatomy of Excretory System of Chordates
3.2.1 Evolutionary development of Kidney
- Archinephros
- Pronephros
- Mesonephros
- Metanephros

3.3 Comparative Anatomy of Nervous System in Vertebrates
3.3.1 Brain
3.3.2 Sense organs – Eyes and Ears

3.4 Comparative Anatomy of Respiration
3.4.1 Gills, Skin and Lungs

3.5 Circulation: Heart and Aortic Arches

3.6 Male and female reproductive and urinary ducts of Vertebrates (Cyclostomes, Teleost, Elasmobranchs, Amphibia, Reptilia, Aves and Mammalia)

Unit 4: Assorted Topics on Chordates **(15L)**

Objectives:

- *To introduce learners with some interesting topics of the chordates.*

Desired outcome:

- *Learners would obtain additional knowledge of diverse characteristics of various chordates*

4.1 Retrogressive metamorphosis in Ascidians

4.2 Pisces

- Evolutionary significance Crossopterygians, Placoderms
- Migration
- Lateral line sense organ and electric organs

4.3 Amphibia – Evolutionary significance of Labyrynthodonts

4.4 Reptilia

- Evolutionary significance of Dinosaurs
- Venom apparatus and biting mechanism in snakes

4.5 Aves

- Migration
- Flight adaptations

4.6 Mammalia

- Dentition in mammals
- Habitat diversification
- Walking gait: Plantigrade, Digitigrade and Unguligrade
- Comparative account of Jaw suspension

Paper 2: PSZO202 Developmental Biology – II

Unit 1: Generalized Account of Reproductive Systems in Chordates (15L)
Objective:

- *To introduce to the learner the generalized account of reproductive systems and accessory structures in chordates.*

Desired outcome:

- *The learner will gain knowledge of reproductive systems in chordates.*

1.1 Reproductive system

- Urochordata – Tunicate
- Cephalochordata – *Amphioxus*
- Cyclostomata – *Petromyzon*
- Pisces – Catfish
- Amphibia – Frog
- Reptilia – Lizard
- Aves – Pigeon
- Mammalia – Human

1.2 Accessory Reproductive Glands – Human

Unit 2: Physiology of Reproduction (15L)
Objective:

- *To acquaint the learner with physiology of reproduction in chordates.*

Desired outcome:

- *The learners will get an idea of reproductive physiology in chordates.*

2.1 Biochemistry of semen – Fish, Frog, Snake, Human.
2.1.1 Sperm capacitation, decapicitation – molecular mechanism and significance

2.2 Ovarian leuteinization and mammary gland differentiation – human

2.3 Pheromones – Pisces, Amphibia, Reptilia, Aves and Mammalia

2.4 Courtship behaviour in – Pisces, Amphibia, Reptilia, Aves, Mammalia

Unit 3: Developmental Biology – Germ Cells, Stem Cells and Induced Breeding (15L)
Objectives:

- *To introduce to the learner the germ cell migration in chordates.*
- *To acquaint the learner with details of stem cells.*

Desired outcome:

- *The learner shall comprehend details of germ cell migration and understand the importance of stem cells.*

3.1 Introduction to germ cells
Germ cell migration in Zebrafish, Frogs, Lizard, Chick and Mouse

3.2 Stem cells –

3.2.1 Embryonic stem cells, Induced Pluripotent stem cells, Adult stem cells

3.2.2 Regeneration Therapy – Cardiac, bone and neuronal regeneration

3.2.3 Cryopreservation of stem cells – Concept, tools, techniques and application

3.3 Induced breeding in fish – technique and applications

Unit 4: Animal Development – Impact of Environment and Evolution (15L)

Objective:

- *To introduce to the learner the impact of environment on development and its evolutionary aspects.*

Desired outcome:

- *The learner will be acquainted with environmental impact on development and evolution of animals.*

4.1 Environmental Cues and Impact on Development

- Predator Induced Polyphenisms – Amphibian
- Temperature and Sex – Fish, Turtle and Alligator

4.2 Teratogenesis

- Alcohol, Retinoic acid, Endocrine disruptors – Diethylstibestrol, Plastics – Nonylphenol, Bisphenol A and Heavy metals as teratogens

4.3 Developmental constraints on evolution – physical, morphogenetic and phyletic

4.3.1 Modularity of development – Example – Duffy blood group substance and Stickleback fish

4.4 Aging and Senescence – Causes, Consequences, and Therapeutics

4.4.1 Environmental and epigenetic causes of aging – Plastics, Pesticides, Heavy metals

4.5 Promoting Longevity: Role of telomerase: an overview

Paper 3: PSZO203: Biochemistry and Biotechnology

Unit 1: Fundamentals of Biochemistry (15L)

Objective:

- *To provide learners an in-depth knowledge of the fundamentals of chemical foundations of biomolecules and their interactions.*

Desired Outcomes:

- *Learners will have in-depth understanding of the fundamentals of chemical basis of life.*
- *Learners will have knowledge of the structures, interactions, and importance of complex biomolecules and their significance in living system.*

1.1 Water as the Basic Molecule of Life

1.1.1 Structure of atoms, molecules and chemical bonds

1.1.2 Molecular structure and solvent properties of water, tetrahedral geometry, hydrogen bond, thermal properties of water and their biological significance

1.1.3 Ionization of water, Ion product of water (*Kw*), Concept of *pH*, Dissociation of weak acids and weak bases, Henderson-Hasselbalch Equation, Titration curves of strong and weak acids, concept of buffer, buffers in biological systems

1.2 Biological Macromolecules

1.2.1 Central role of Carbon

1.2.2 Common ring structure, Chirality, and Isomerization in biomolecules

1.2.3 Composition, structure of monomers and polymers, functions of carbohydrates, lipids, proteins, nucleic acids and vitamins

1.3 Interactions of Macromolecules

1.3.1 Stability of Proteins and Nucleic Acids; Stabilizing Interactions such as *Vander Waals,* Electrostatic, Hydrogen Bonding, Hydrophobic Interactions

1.3.2 Conformation of proteins: Ramachandran plot, secondary structure, domains, motif and folds, hydropathy index of amino acids, isoelectric point (*pi*) of proteins

1.4 Complex biomolecules

1.4.1 Glycoproteins: blood group determinants

1.4.2 Complex Lipids: Phospholipids, Sphingolipids, Gangliosides, Sterols and Waxes

1.4.3 Lipoproteins: classification and functions of chylomicrons, VLDL, LDL, HDL, and free fatty acid-albumin complex

Unit 2: Metabolism and Metabolic Pathways (15L)

Objective:

- *To provide the learners knowledge of the metabolism of various biomolecules and the importance and interrelationships of metabolic pathways in the biological systems.*

Desired Outcomes:

- *Learners' will have in-depth understanding of the bioenergetics and metabolic pathways of various biomolecules.*
- *Learners will gain knowledge of the regulatory mechanisms underlying various metabolic pathways*.

2.1 Biochemical Thermodynamics

2.1.1 Laws of thermodynamics, free energy, entropy, enthalpy, exergonic and endergonic reactions

2.1.2 Biological oxidation: Electron transport chain in mitochondria; oxidative phosphorylation – mechanism, uncoupling of oxidative phosphorylation and its significance

2.1.3 Free radicals, Antioxidants and Antioxidant system

2.2 Carbohydrate and Lipid Metabolism

2.2.1 Glycolysis and its energetics

2.2.2 Gluconeogenesis: Reaction sequence from pyruvate, gluconeogenesis from amino acids, glycerol, propionate and lactate

2.2.3 Glycogen metabolism: Glycogenesis, Glycogenolysis

2.2.4 Significance of the pathways: Hexose Monophosphate (HMP) Shunt as a multifunctional pathway; uronic acid pathway; glyoxalate cycle

2.2.5 Fatty acid metabolism: Oxidation of saturated even and odd carbon atom, and unsaturated fatty acids, metabolism of cholesterol

2.3 Regulation of Metabolism

2.3.1 Regulation of metabolic flux by genetic mechanisms: Control of enzyme synthesis, constitutive and inducible enzymes; induction and repression of enzymes (lac operon and trp operon)

2.3.2 Regulation of metabolism by extracellular signals: nutrient supply, nutrient transport, endocrine control, neural control

2.4 Amino acid and Nucleic acid Metabolism

2.4.1 Nitrogen metabolism: Protein turnover, amino acid pool, nitrogen balance

2.4.2 Metabolism of Amino acids: Transamination, Deamination, Urea cycle

2.4.3 Formation of amino acids from Pyruvate, TCA cycle intermediates, Acetyl CoA

2.4.4 Nucleic Acid metabolism: *De novo* synthesis: synthesis of purine and pyrimidine nucleotides; Salvage Pathway; Catabolism of purine and pyrimidine nucleotides

Unit 3: Processes and Techniques in Biotechnology (15L)

Objectives:

- *To provide the learners thorough knowledge on the genome organization, gene expression and its control in prokaryotes and eukaryotes.*
- *To acquaint learners with the basic tools and techniques used in Biotechnology.*

Desired Outcomes:

- *Learners will be able to understand the processes for harnessing the potentials of living systems for betterment of mankind.*
- *Learners will have an understanding of the processes and techniques used in development of biotechnology products.*

3.1 Genome Organization

3.1.1 Organization of genome in prokaryotes and eukaryotes, C-value paradox and genome size

3.1.2 Complexity of viral, bacterial and eukaryotic genomes, Cot curves, repetitive and non-repetitive DNA sequences

3.2 DNA replication, Gene expression in prokaryotes and eukaryotes

3.2.1 Molecular model of DNA replication

3.2.2 Transcription and translation in prokaryotes

3.2.3 Transcription and translation in eukaryotes

3.3 Control of gene expression in Prokaryotes & Eukaryotes

3.3.1 Small regulatory RNAs, small nuclear ribonucleoproteins (snRNPs), Transcription level control, RNA processing, Translational level control, post-translational control

3.3.2 Gene silencing, miRNA, RNA silencing pathways and DNA methylation

3.4 Methods in Biotechnology

3.4.1 Cloning using plasmid pUC18, pUC19, detection of recombinants by blue-white screening, cloning in bacteriophage, cosmid, BAC and YAC vectors

3.4.2 Chromosome walking, RAPD, AFLP, Microarrays

Unit 4: Applications of Biotechnology (15L)

Objective:

- *To provide learners the knowledge on the applications of biotechnology in various fields.*

Desired outcome:

- *Learners will gain knowledge on the application of biotechnology in industries, medicines, agriculture and environment.*

4.1 Industrial Biotechnology

4.1.1 Microbial fermentation, Microbial growth kinetics, Design of a fermenter, Organisms used in large scale fermentation.

4.1.2 Production of antibiotics – Cephalosporin, erythromycin; amino acids – proline, glutamate; vitamins – cyanocobalamine, riboflavin; Aspartame and Taxol

4.2 Medical Biotechnology: Molecular approaches in diagnosis and treatment

4.2.1 Peptide vaccines: synthetic drugs (engineered proteins)

4.2.2 Genetic immunization: Antisense DNA, Therapeutic ribozymes

4.2.3 Anti-idiotypic vaccine for cancer treatment

4.2.4 Monoclonal antibodies (mAbs) and their therapeutic applications

4.2.5 HIV therapeutic agents

4.2.6 Production of biopharmaceuticals from transgenic animals – Human Tissue Plasminogen Activator (hTPA) and α-1Antitrypsin (AAT)

4.2.7 Pharmacogenomics and Nutrigenomics: An overview and applications

4.3 Agricultural Biotechnology

4.3.1 Plant Tissue culture methods–Broad outline and applications of Pollen culture & Protoplast culture

4.3.2 *Bacillus thuringiensis* based bio-pesticides, genetic engineering of herbicide resistance trait in crops, genetic engineering of β-carotene biosynthetic pathway in golden rice

4.3.3 Genetic engineering of biological nitrogen fixation (Nitrogen as ecluster and hydrogenase genes), Genetic engineering drought/salinity tolerance trait in crops

4.4 Environmental Biotechnology

4.4.1 Effluent treatment, Bioremediation, phytoremediation, Biosensors, Biofuels

4.4.2 Cartagena protocol on biosafety – General features with respect to objectives, precautionary principle and live modified organisms (LMO)

Paper 4: PSZO204: Research Methodology

Unit 1: Principles of Scientific Research (15L)

Objectives:

- *To acquaint learners with the principles of scientific research and methods of conducting scientific enquiry.*
- *To inculcate scientific temperament and research aptitude among the learners.*

Desired outcome:

- *Learner will be able to formulate research problem and concept research design.*
- *Learner will be able to execute the research problem.*

1.1 Basic concepts of research

1.1.1 Definition

1.1.2 Characteristics of research (controlled, rigorous, systematic, valid and verifiable, empirical and critical)

1.1.3 Objectives of research

1.1.4 Types of research:

a) Pure and applied

b) Structured and unstructured

c) Descriptive, correlational, explanatory, exploratory, historical, comparative and experimental

1.2 Formulating research problem

1.2.1 Reviewing literature: Using library, computerized searches, evaluating literature

1.2.2 Developing a research problem: Importance, sources, considerations, steps, defining a problem, formulate objectives

1.2.3 Identifying variables: Introduction, types of variables, measurement scales

1.2.4 Hypothesis: Definition, function, characteristics, types (H_0, H_A), Principles of hypothesis, framing hypothesis, errors in hypothesis, research question versus research hypothesis, hypothesis versus non-hypothesis research

1.3 Research design

1.3.1 Definition and purpose

1.3.2 Characteristics of good research design

1.3.3 Sampling strategy and sampling size determination, eliminating extraneous variables

1.3.4 Types of study design: study designs in quantitative research (cross-sectional, before and after, longitudinal, retrospective, prospective, retrospective-prospective, experimental, non-experimental, quasi-experimental)

Unit 2: Data Management and Analysis (15L)

Objectives:

- *To introduce learners to various statistical tools for analysis of research data.*
- *To familiarize learners with the in-silico approach for data management.*

Desired outcome:

- *The learner will be able to develop skill set for organisation and effective presentation of data.*

- *The learner will be able to choose correct statistical test.*
- *The learner will be able to perform statistical analysis indifferent fields of research using various computer programs.*

2.1 Methods of data collection

2.1.1 Primary sources
2.1.2 Secondary sources

2.2 Data Classification and Presentation

2.2.1 Classification of data (Geographical, Chronological, Qualitative, Quantitative)
2.2.2 Tabulation of data (one-way table, two-way table, complex table)
2.2.3 Type of charts (Line, Column, Scatter plot, Box plot, Heat Map)

2.3 Concepts of Measurements

2.3.1 Univariate (standard deviation, variance, quartiles)
2.3.2 Bivariate (correlation and regression)
2.3.3 Multivariate (ANOVA: one-way, two-way)
2.3.4 Level of significance and p-value
2.3.5 Normal distribution, Skewness, Kurtosis, Outliers

2.4 Testing of Hypothesis

2.4.1 Null hypothesis, Alternative hypothesis
2.4.2 Type 1 and Type 2 Errors
2.4.3 Testing of Hypothesis (single population mean, two population means)
2.4.4 One-tailed and Two-tailed tests

2.5 Parametric and Non-parametric tests

2.5.1 Parametric tests: t test, z test, F test
2.5.2 Non-parametric tests: Chi-square test, Mann-Whitney test, Kruskal-Wallis test, Friedman Test, Wilcoxon signed-rank test

Unit 3: Scientific Communication (15L)

Objectives:

- *To enable learners to develop skills for effective research communication.*
- *To enable learners to publish research paper in journals with good impact factors.*

Desired outcome:

- *The learner will be able to get an insight of scientific communication documentation and will become familiar with good scientific journals.*

3.1 Research planning

3.1.1 Project Proposal and research funding agencies – Research grants, scholarships and funding (CSIR, DBT, DST, DST- INSPIRE Fellowship, ICMR, INSA, BRNS, MoEFCC, UGC-RFSMS, Fulbright Fellowships for Indian students, Lady Tata Memorial Trust, EPA, Bill and Melinda Gates Foundation, Wellcome Trust, Erasmus Mundus)
3.1.2 Use of reference management software (MS Word / Zotero / Mendeley)
3.1.3 Scientific writing –Thesis and Dissertation

3.2 Documentation for approval from Institutional Animal Ethics Committee (IAEC) and

Institutional Biosafety Committee (IBSC)

3.2.1 Documents for registration, renewal and reconstitution of IAEC as per CPCSEA guidelines
3.2.2 Proposal layout for permission from IAEC for use of animals in research
3.2.3 Proposal layout based on recombinant DNA safety guidelines from IBSC
3.2.4 Proposal layout for use of transgenic animals in research

3.3 Publications and Research Journals

3.3.1 Types of research journals
3.3.2 Impact factors of Journals
3.3.3 Predatory Journals
3.3.4 Review process - benefits and drawbacks of single blind, double blind and open peer review process
3.3.5 Understanding "h – index" and "i10 – index"
3.3.6 SCOPUS, Google Scholar, Web of Science
3.3.7 Process to obtain ISSN and ISBN

Unit 4: Model organisms and their applications (15L)

Objectives:

- *To introduce to learners the key species which are used as model organisms in research.*
- *To acquaint the learners with special techniques developed for studying these model organisms.*
- *To make them aware of the contributions of model organisms to basic biology, genetics, development and diseases.*

Desired outcome:

- *The learners will be able to understand the special features of different animals that have made them useful as a model system.*
- *The learners will become familiar with the specific applications of model organisms for various biological processes.*
- *The learners will be able to appreciate how experimentation with these organisms has enhanced the understanding of the basis of human diseases.*

4.1 Introduction: Concept key features and importance of model organisms

4.2 Earthworm

4.2.1 Biology and genome
4.2.2 Model for studies on regeneration

4.3 *Caenorhabditis elegans*

4.3.1 Body plan of the worm, genetics, genome, cultivation, advantages and limitations
4.3.2 Techniques used for genetic modification, Mutant characterization, discovery of RNAi

4.4 *Daphnia sp.*

4.4.1 Genome, epigenetic phenotypic variation
4.4.2 Advantage and limitations
4.4.3 Model for studies in toxicology

4.5 *Drosophila melanogaster*

4.5.1 Genome, advantages and limitations

4.5.2 Model for cytogenetics, development, neuroscience, human diseases and therapeutic drug discovery

4.6 *Danio rerio* (Zebra fish)

4.6.1 Genome, advantages and limitations

4.6.2 Insights on embryology, ageing and toxicology

4.7 *Mus musculus* (Mouse)

4.7.1 G enomics, advantages and limitations

4.7.2 Model for studies on physiology, development, ageing, human diseases (Cancer and Diabetes) and behaviour research

4.7.3 Transgenic and germ line transgenic mouse models, genetically engineered mouse models (GEMMs): Knock-In and Knock-out mouse models

M. Sc. Part 1: Semester II Practical 1
PSZOP201: Chordates

1. Museum specimens / Photographs / Pictures / Slides:
    i. Protochordates: Study of *Doliolum, Herdmania, Ascidia, Botryllus*
    ii. Adaptive radiation in Reptiles-Turtles, Crocodile, Tuatara, Snakes and Lizards
    iii. Adaptive radiation in Mammals – Talpa (mole), Tarsius, Armadillo, Camel and Sperm whale
2. Comparative anatomy of digestive system in vertebrates.
3. Comparative study of Pelvic and Pectoral girdle in vertebrates.
4. Types of jaw suspension in vertebrates- Autodiastylic, Holostylic, Amphistylic and Autostylic.
5. Types of vertebrae – Acoelous, Procoelus, Opisthocoelus, Amphicoelus, Amphiplatins, Heterocoelus, Axis and atlas vertebrae.
6. Phylogenetic analysis of phenotypic characters from given data in chordates.
7. Construction of phylogenetic tree with given ancestors.
8. Pigeon – Study / Virtual dissection of
    i. Flight muscles
    ii. Digestive system
    iii. Respiratory system
    iv. Circulatory system
    v. Excretory system
    vi. Reproductive system – male and female
9. Field visit to National park / Sanctuary / Museum / Zoo or any other suitable ecosystem to study vertebrates.

Practical 2 PSZOP202: Developmental Biology II

1. Identification of fish developmental stages–egg, larva, juvenile (fry, fingerling and adult).
2. Measurement of fish ova diameter using oculometer.
3. Preparation of histological slides – fish ovary / testis.
4. Study of metamorphosis in Amphibia.
5. Histology of male and female accessory reproductive glands – Human – Prostate gland, Bulbourethral gland and placenta [Permanent slides].
6. Analysis of testicular extract/ semen – Fish / Chicken / Goat.
    i. pH, Viscocity, Agglutination.
    ii. Sperm count and motility – Fish / Chicken / Goat.
    iii. Hypo-osmotic swelling of sperm – Normal / Abnormal.
7. Study of stem cells from chick embryo – staining and identification of cells.

Practical 3 PSZOP203: Biochemistry and Biotechnology

1. Titration curve of weak acid.
2. Titration curve of strong acid.
3. Quantitative estimation of proteins from the given sample using Bradford method.
4. Determination of glucose by Benedict's quantitative reagent (Titrimetric method).
5. Isolation and determination of glycogen in the given tissue (liver / skeletal muscle / kidney) by Anthrone method.
6. Determination of saponification value of fats/oils.
7. Estimation of the number of bacteria in the given culture by nephelometry.
8. Preparation of beads by immobilization of yeast cells in calcium alginate.
9. Monitoring of Invertase activity in bioreactor column of immobilized yeast cells by DNSA method.
10. Restriction digestion of the given DNA sample and separation of the fragments by agarose gel electrophoresis.
11. Southern blotting technique (assembly of the sandwich/ mechanical blotting).
12. Determination of effect of minimal and enriched media on growth curves of *E. coli.*

Practical 4 PSZOP204: Research methodology

1. Write a proposal to obtain permission for use of model animal in research from IAEC. (*Print copy to be submitted during practical exam and assessed by viva.*)
2. Write a grant proposal to a funding agency. (*Print copy to be submitted during practical exam and assessed by viva.*)
3. Evaluation of journal / research paper metrics:
   a. Impact factor (from the given data)
   b. h – index (from the given data)
   c. Percent plagiarism (using online tools)
4. Interpret the given data (qualitative / quantitative) and represent as graph / chart.
5. Problems based on parametric tests and non-parametric tests. (to be performed using MS Excel / SPSS / Minitab)
6. Calculation of correlation co-efficient and plotting regression line from given biometry data using MS Excel / SPSS / Minitab.
7. Calculation of diversity indices (Shannon and Simpson) using MS Excel / PAST3.
8. Descriptive / Inferential statistics using online statistical tests – GraphPad Prism
9. https://www.graphpad.com/data-analysis-resource-center/
10. To study the characteristics and applications of animal models used in pre-clinical research.
11. Small animal models: Rat, Transgenic mice, Nude mice, Hamster.
12. Large animal models: Rabbit, *Cynomolgus macaque*, Rhesus macaque, Vervet / African green monkey, Marmoset, Chimpanzee.
13. Visit to an animal house in a research institution and submission of report.

References Semester 2

PSZO201

1. Introduction to Genera Zoology, Volume II– K. K. Chaki, G. Kundu, S. Sarkar (NCBA)
2. Vertebrate Zoology– F. B. Mondal (Oxford IBH)
3. Modern TextBook of Vertebrates – R. L. Kotpal (Rastogi)
4. Alexander, R. M. The Chordata. Cambridge University Press, London.
5. Barrington,E. J. W. The biology of Hemichordata and protochordata. Oliver and Boyd, Edinborough.
6. Kingsley, J. S. Outlines of comparative autonomy of vertebrates. Central Book Depot, Allahabad.
7. Kent, C. G. Comparative anatomy of vertebrates.
8. Smith, H. S. Evolution of chordate structure. Hold Rinehartand Winstoin Inc., New York.
9. Torrey, T. W. Morphogenesis of vertebrates. John Wiley and Sons Inc., New York.
10. Romer, A. S. Vertebrate Body, III Ed. W. B. Saunders Co., Philadelphia
11. Young, J. Z., Life of mammals, The Oxford University Press, London
12. Colbert, E.H., Evolution of the vertebrates. John Wiley and Sons Inc., New York.
13. Weichert, C. K. and Presch, W. Elements of Chordate anatomy.4th Edn. McGraw Hill Book Co., New York.
14. Montagna, W. Comparative anatomy. John Wiley and Sons Inc.
15. Andrews, S. M. Problems in vertebrate evolution. Academic Press, New York.
16. Waterman, A. J. Chordata structure and function. Macmillan Co., New York.
17. Lovtrup, S. The phylogeny of vertebrate. John Wiley & Sons, London
18. Barbiur, T. Reptiles and Amphibians: Their habits and adaptations. Hongton Miffin Co., New York.
19. Smyth. Amphibia and their ways. The Macmillan Co., New York.
20. Jordan and Verma. Chordate Zoology, S. Chand Publication.

PSZO202

1. Comparative embryology of the vertebrates 1 – 2 (1953) McGraw – Hill Book company, New York.
2. Comparative reproductive biology - HeideSchatter and Gheorghe Constantinescu – Blackwell Publishing.
3. Human reproductive system – Encyclopedia Britannica by Richard J. Harrison.
4. Animal Physiology – Withers.
5. Animal Physiology - Hoar
6. Developmental Biology- Scott F.
7. Gilbert, 9th Edition.
8. Animal Physiology - Giese
9. Chordates- Jordan and Verma
10. Chordates- Parker and Haswell
11. Chick embryology- Patten
12. Chordate Zoology- Kotpal
13. Chordate Zoology-P. S. Dhami and J. K. Dham
14. Sex pheromones in amphibians-a review Vet.Med-Czech, 50,2005(9); 385-389
15. http://www.eurekaselect.com/node/156190/related-ebooks
16. https://embryo.asu.edu/pages/sperm-capacitation
17. https://www.sciencedirect.com/book/9780124366435/handbook-of-stem-cells
18. https://ivf.net/ivf/a-textbook-of-in-vitro-fertilization-and-assisted-reproduction-the-bourn-hall-guide-to-clinical-and-o418.html
19. https://www.britannica.com/science/teratogenesis
20. https://link.springer.com/chapter/10.1007/978-3-642-45532-2_15
21. https://www.elsevier.com/books/handbook-of-the-biology-of-aging/schneider/978-0-12-627871-2
22. https://www.whatisepigenetics.com/fundamentals/

PSZO203
Biochemistry

1. Puri, Dinesh (2014). Textbook of Medical Biochemistry (3rd Edition).
2. Bhagavan N. V. and Chung-Eun Ha (2015).Essentials of Medical Biochemistry (2nd Edition).
3. Harper's Illustrated Biochemistry.
4. Satyanarayana U. and Chakrapani (2014).Biochemistry.
5. Outlines of Biochemistry, (5th Edition) – 2006 – Eric E. Conn, Paul K. Stumpf, George Bruening.
6. Lehninger, L. Albert, David, L. Nelson, Michael, M. Cox (1993). Principles of Biochemistry, CBS Publishers and Distributors, Delhi.
7. Stryer, L (1988), Biochemistry, W.H. Freeman and Company, New York.
8. Cooper, T. G (1977), The Tools of Biochemistry, Wiley Interscience Publication, John Wiley and Sons, New York.
9. Smith (1983), Principles of Biochemistry, (7th Edition), Mc Graw Hill (Mammalian Biochemistry), New York.
10. Voet, D. & Voet, J (1995), Biochemistry, John Wiley and Sons, New York.
11. Basic Concepts in Biochemistry – Hiram F Gilbert –McGraw Hill Publications.
12. Fundamentals of Biochemistry – J L Jain, Sunjay Jain, Nitin Jain – S. Chand.

Biotechnology

1. Molecular Cell Biology (5th Edition) – Lodish, Berk, Matsudaira, Kaiser, Krieger, Scott, Zipursky, Darnell – WH Freeman.
2. Cell & Molecular Biology: Concepts & Experiments (6th Edition) – Gerald Karp.
3. iGenetics – A molecular approach (3rdEdition) – Peter J Russell – Pearson Education Inc.
4. Molecular Biotechnology – Principles and applications of recombinant DNA (3rd Edition) – Bernard R Glick &Jack J Pasternak – ASM Press.
5. Principles of Fermentation Technology (2nd Edition) – Peter F Stanbury, Allan Whitaker, Stephen J Hall – Elsevier Publications.
6. Basic Biotechnology (3rd Edition) – Colin Ratledge & Bjorn Kristiansen – Cambridge University Press.
7. Medical Biotechnology – S. N. Jogdand – Himalaya Publishing House.
8. Microbial Biotechnology (2nd Edition) – Alexander Glazer & Hiroshi Nikaido – Cambridge University Press.
9. Plant Tissue Culture: Theory and Practice – S. S. Bhojwani & M. K. Razdan – Elsevier.
10. Molecular Biology and Biotechnology– KG Ramawat & Shaily Goyal – S. Chand.
11. Aspartame Information Center.www.aspartame.org
12. Genetic engineering of taxol biosynthetic genes in Saccharomyces cerevisiae. a. Biotechnology and Bioengineering 93(2): 212-24 • February 2006
13. The Golden Rice Project http://www.goldenrice.org/

Additional Reading:

1. Molecular Biology of the Cell – Alberts et al., - Garland Science.
2. Molecular Biology of the Gene – Watson et al., Benjamin Publications.
3. Genes VIII – Benjamin Lewin –Oxford Press.
4. Molecular Biology – Freifelder – Narosa Publication House.
5. Textbook of Biotechnology – H K Das – Wiley India Publication.

PSZO204

Principles of Scientific Research:

1. Graduate research - A guide for students in Life Sciences. 2nd edition. Robert V. Smith
2. Research methods for Biosciences. 3rd edition. Debbie Holmes, Peter Moody, Diana Dine, Laurence Trueman
3. Experimental designs for Life Sciences. 4th edition. Graeme D., Ruxton and Nick Colegrave
4. Research methodology - Step by Step Guide for Beginners. 3rd edition. Ranjit Kumar
5. Research methodology - Tools and techniques, Bridge Centre 2015

Data Management and Analysis:

1. The practice of statistics in life sciences - Brigitte Baldi and David Moore, W. H. Freeman.
2. Mahajan's methods in Biostatistics for Medical students and Research Workers - Bratati Banerjee, Jaypee Publishers.
3. Biostatistics: Basic concepts and methodology - Wayne Daniel and Chad Cross, Wiley.
4. Biostatistical analysis - Jerrold H. Zar, Pearson.
5. Statistics for people who (think they) hate statistics – Neil J. Salkind, SAGE Publications.
6. Discovering Statistics using IBM SPSS Statistics – Andy Field, SAGE Publications.
7. IBM SPSS Statistics Step by Step – Darren George and Paul Mallery, Taylor & Francis.
8. Statistics for Ecologists using R and Excel – Mark Gardener, Pelagic Publishing.

Scientific Writing:

1. Thesis and Dissertation Writing in a Second Language a handbook for supervisors - Brian Paltridge and Sue Starfield, Routledge Publishers.
2. The process of research writing - Steven Krause – Eastern Michigan University.
3. Animal - Use Research IAEC Project Proposal & animal imports Guidelines – NCBS Animal Care and Resource Center.
4. Academic Writing and Publishing – A Practical Handbook – James Hartley.
5. How to Improve Your Journal and Have Greater Impact – James Testa – Thomson Reuters.
6. https://beckerguides.wustl.edu/authors/hindex
7. https://www.elsevier.com/en-in/reviewers/what-is-peer-review
8. https://www.thehindu.com/sci-tech/science/what-is-a-predatory journal/article21039351.ece

Model Organisms and their applications:

1. Introduction to Genetic Analysis: Griffiths, Wessler, Lewontin, Carroll. WH Freeman Company, New York.
2. Biology. E. P. Solomon, L. R. Berg, D. W. Martin, Thompson Brooks/Cole.
3. Bier, E. 2005. Drosophila, the Golden Bug, Emerges as a Tool for Human Genetics. Nature Reviews Genetics 6: 9-23.
4. Howe K et al. The zebra fish reference genome sequence and its relationship to the human genome. Nature 2013.
5. Pennisi, E. (1998). Worming secrets from the C. elegans genome. Science, 282, 1972-1974.
6. Fly: http://flybase.bio.indiana.edu:82/
7. Worm: http://www.expasy.ch/cgi-bin/lists?celegans.txt
8. Zebrafish: http://www.ncbi.nlm.nih.gov/genome/guide/D_rerio.html
9. Mouse: http://www.informatics.jax.org/

Modality of Assessment:

A) Internal Assessment- 40%

Sr. No.	Evaluation type	Total Marks
1.	One Assignments/Case study/Project	25
3.	Active participation in routine class instructional deliveries	05
4.	Attendance – (0-25%=0 marks, 25-50%=1mark,50-75%=3 marks and 75-100%= 5 marks)	05
5.	Overall conduct as a responsible student, manners, skill in articulation, leadership qualities demonstrated through organizing co-curricular, etc.	05

B) External examination 60%

a) Semester End Theory Assessment- 60% **60 Marks**

i) Duration – These examinations shall be of two and half hours duration for each paper.

ii) Theory Question Paper Pattern:

- There shall be five questions each of 12 marks. On each unit there will be one question and the first one will be based on entire syllabus.
- All questions shall be compulsory with internal choice within the questions. Each question will be of 18 to 20 marks with options.
- Question may be subdivided into sub-questions a, b, c… and the allocation of marks depend on the weightage of the topic.

b) Practicals **50 Marks**

University of Mumbai
M.Sc. ZOOLOGY
Semester I / Semester II EXAMINATION
Course PSZO

Maximum Marks: 60 **Duration: 2.5 Hours** **Marks Option: 90**

Question 1: Based on Unit I to IV (Mixed Questions)

Question 2: Based on Unit I

Question 3: Based on Unit II

Question 4: Based on Unit III

Question 5: Based on Unit IV

Instructions:

i. All questions are compulsory.
ii. All questions carry equal marks.
iii. Draw neat and labeled diagrams wherever necessary.

1. Answer any **three questions** from the following(Based on all 4 units)
   a. 04
   b. 04
   c 04
   d 04
   e 04

2. Answer any **two questions** from the following(Based on Unit1)
   a. 06
   b. 06
   c. 06

3. Answer any **two questions** from the following (BasedonUnit2)
   a. 06
   b. 06
   c. 06

4. Answer any **two questions** from the following (Based on Unit 3)
   a. 06
   b. 06
   c. 06

5. Answer any **two questions** from the following (Based on Unit 4)
   a. 06
   b. 06
   c. 06

PRACTICAL EXAMINATION PSZOP101

Time: 10 am to 2 pm **Total Marks: 50**

Q.1 To study Nervous / Reproductive System of Clamworm / Prawn / *Pila* / Starfish / *Balanoglossus*. **06**

Q.2 To Study Digestive / Excretory system of Clamworm / Prawn / *Pila* / Starfish / *Balanoglossus*. **06**

Q.3 Identify and describe the larva of: (preferably slides / specimens available) **04**

a. Annelida / Arthropoda
b. Mollusca / Echinodermata

Q.4 Identify and describe fossils:

a. Annelida / Arthropoda **03**
b. Mollusca / Echinodermata / Hemichordata **03**
c. Annelida / Arthropoda / Mollusca / Echinodermata / Hemichordata **03**

(This specimen c should be out of syllabus, but should show clear characters of the phylum)

Q.5 Making fossil cast out of clay / muddy soil and viva based on it. **05**

Q.6 Field visit report and viva based on field visit. **10**

Q.7 Viva based on theory. **05**

Q.8 Journal. **05**

PRACTICAL EXAMINATION PSZOP102

Time: 10 am to 2 pm **Total Marks: 50**

Q.1 Major question: **14**

To study conjugation and binary fission in *Paramecium* from given culture.

OR

To study life cycle of *Drosophila.*

Q.2 Minor question: **08**

To observe development of *C. elegans.*

OR

To observe stages of *Tribolium* or *Sitophilus.*

Q.3 Identification: (3 marks each) **18**

a) Gemmule / Germ layer
b) Larva – Porifera / Cnidarian / Annelida
c) Larva – Mollusca / Crustacea
d) Larva – Echinodermata / Hemichordata
e) Life Cycle of Butterfly / Moth
f) Coelom

Q.4 Viva. **05**

Q.5 Journal. **05**

PRACTICAL EXAMINATION PSZOP103

Time: 10 am to 2 pm **Total Marks: 50**

Q.1 DNA isolation / Kappa particles in *Paramecium* / Maternal effects in *Drosophila.* **10**

Q.2 Identify and describe: **10**
Parental care / Evolution of Brood Parasitism – Cuckoo or Crow / Reciprocal altruism – Vampire Bat / Thumping of Ground Gene – Rabbit / Klepto parasitic fledglings associated with reduced success in host family in barn owl.

Q.3 Identify the following: (2 marks each): **14**

a) Comparison of Hemoglobin
b) Type of Fossil
c) Type of Fossil
d) Example of Cloning
e) Example of Cloning
f) Syndrome
g) Syndrome

Q.4 Two problems based on gene mapping and mitotic index. **06**

Q.5 Viva. **05**

Q.6 Journal. **05**

PRACTICAL EXAMINATION PSZOP104

Time: 10 am to 2 pm **Total Marks: 50**

Q.1 To determine concentration of Iron as a pollutant from sample / sample solution by redox titration or spectrophotometric method. **12**

OR

To estimate the amount of dust (particulate matter) deposited on the leaves of roadside plants.

OR

To detect heavy metals from the sample water – Zinc / Lead / Copper.

Q.2 Identify and describe **12**

a) Chronobiology
b) Imaging technique
c) Imaging technique
d) Climate change / global warming indicator animal
e) Climate change / global warning indicator animal
f) Anatomical regions of brain involved in stress and emotion

Q.3 Assignment –submission of report on pulse rate after stress. **06**

Q.4 Submission of report on visit to nearby DNA barcoding laboratory / medical Imaging center. **05**

Q.5 Environment audit report (Green audit / EIA of small selected area). **05**

Q.6 Viva-voce. **05**

Q.7 Journal. **05**

PRACTICAL EXAMINATION PSZOP201

Time: 10 am to 2 pm **Total Marks: 50**

Q.1 a. Study of Pigeon – digestive / circulatory / respiratory system. **06**

b. Study of Pigeon – excretory / male reproductive / female reproductive / flight muscles. **04**

Q.2 Identify and describe as per the instructions. **15**

a. Identify and describe (any Protochordate)
b. Identify and comment on its adaptive radiations(Reptilia / Mammalia)
c. Identify and comment on comparative account of digestive system (Fish / Frog / Lizard / Pigeon / Rat).
d. Identify and comment on any type of jaw suspension.
e. Identify and comment on type of (vertebrae / pelvic girdle / pectoral girdle).

Q.3 Make a phylogenetic analysis of phenotypic characters from given data / Construct phylogenetic tree on the basis of given data. **05**

Q.4 Field visit report and viva based on it. **10**

Q.5 Viva-Voce based on theory. **05**

Q.6 Journal. **05**

PRACTICAL EXAMINATION PSZOP202

Time 10: 00 AM to 2: 00 PM **Total Marks: 50**

Q.1 Estimate the pH and viscosity/ pH and agglutination/Viscosity and agglutination from Fish / Chick / Goat semen. **10**

OR

Determine the sperm count and motility from Fish / Chick / Goat semen.

OR

Determine the hypo-osmotic swelling of sperm – Normal / Abnormal.

Q.2 Determine the diameter of the ova from suitable fish using occulometer. **15**

OR

Prepare block / ribbon / stained slides for histological study of fish ovary / testis.

OR

Stain and identify the stem cells from chick embryo.

Q.3 Identify and describe **15**

a) Histology of accessory reproductive glands / organ (Prostrate / Bulbourethral / T.S of placenta)
b) Histology of accessory reproductive glands /organ (Prostrate / Bulbourethral / T.S of placenta)
c) Study of metamorphosis in Amphibia (any one stage)
d) Fish developmental stages – Egg / larva
e) Fish developmental stages – fry / fingerling

Q. 4 Viva-Voce. **05**

Q. 5 Certified journal. **05**

PRACTICAL EXAMINATION PSZOP203

Time: 10.0 AM to 2.00 PM **Total Marks: 50**

Q.1 Determine the *pKa* of weak acid/ Perform titration of strong acid and prepare the titration curve. **16**

OR

Estimate the invertase activity in bioreactor column of immobilized yeast cells by DNSA method.

OR

Estimate glucose by Benedict's quantitative reagent (Titrimetric method).

Q.2 Estimate quantitatively the proteins from the given sample using Bradford method. **14**

OR

Isolate and determine glycogen in the given tissue (liver/ skeletal muscle / kidney) by Anthrone method.

OR

Determine saponification value of fats /oils.

OR

Determine effect of minimal /enriched media on growth curves of *E. coli*.

OR

Estimate the number of bacteria in the given culture by Nephelometry.

Q.3 Prepare calcium alginate beads for immobilization of yeast cells. **10**

OR

Perform restriction digestion of the given DNA sample and separate the fragments by Agarose Gel Electrophoresis.

OR

Perform the assembly for Southern blotting technique (Mechanical / Physical blotting).

Q.4 Viva-voce. **05**

Q.5 Certified Journal. **05**

PRACTICAL EXAMINATION PSZOP204

Time: 10:00 am – 02:00 pm **Total Marks: 50**

Q.1 Perform a parametric test on the given data using MS Excel / SPSS / Minitab and interpret the result. **12**

OR

Perform a non-parametric test on the given data using MS Excel /SPSS / Minitab and interpret the result.

OR

Calculate correlation co-efficient and plot a chart with regression line from the biometry data provided using MS Excel / SPSS / Minitab and interpret the result.

OR

Calculate biodiversity indices of the given data using MS Excel / PAST3 and interpret the result.

Q.2 A. Perform descriptive statistics of the given data using MS Excel / SPSS / Minitab and interpret the result. **06**

OR

Interpret the type of data provided and represent it in relevant chart using MS Excel / SPSS / Minitab.

OR

Perform descriptive / inferential statistics using online resources provided at Graph Pad Prism – Quick Calcs.

B. Calculate from the given data– a) Impact factor and b) h-index. **04**

OR

Estimate percent plagiarism from the text provided and comment on the results.

Q.3 Identify the model organisms and comment on their applications (a– d). **12**
a and b – small animal models
c and d – large animal models

Q.4 Report of visit to animal house in a research institution. **05**

Q.5 Submission of proposal to IAEC / Application for grant from funding agency and viva based on it. **06**

Q.6 Certified Journal **05**

****