2017-2018

Programme Code	Programmename	Year of Introduction	Statusof implementationof CBCS/Elective CourseSystem (ECS)	Yearof implementation of CBCS/ECS	Yearofrevision (ifany)	Ifrevisionhas beencarriedout in thesyllabus duringthelast5 years, Percentageof Contentaddedor replaced	Linktothe relevant documents
			CBCS: Yes/No ECS:Yes/No	CBCS: ECS:	CBCS: ECS:	CBCS ECS	CBCS: ECS:
VIR	M.Sc Virology	1988	CBCS: Yes ECS:Yes	2016 2017	2017-2018	CBCS: 10 to 25 ECS: 10 to 25	CBCS ECS

Sri Venkateswara University
Department of Virology

M.Sc. VIROLOGY PROGRAMME

TO BE IMPLEMENTED WITH EFFECT FROM THE ACADEMIC YEAR 2017-201

SYLLABUS

Choice Based Credit System (CBCS)

Program code	Program Name	Name of the Department
VIR	M. Sc. Virology	Dept. of Virology

Vision:

To serve as a "centre for academic excellence" by assuring systematic and focussed teaching and research in the frontier areas ofVirology and to provide a conducive environment to the students for learning and quality training to promote professional development and individual well-being.

Mission:

1. Providing quality post graduate education of high standards in Virology and achieving excellence in teaching and research.
2. Introducing students to basic and advanced concepts/technologies/methods related to identification, characterization, detection and management of economically important, emerging and reemerging viruses infecting microbes, plants, animals and humans along with widepractical frameworks that can provide quality training of international standardsand employability opportunities.
3. Pursuing cutting edge research in the key areas of Virology and MicrobiologicalSciences through sponsored research projects.
4. Establishing national/international collaborations with premier research institutes/universities for advancing scientific knowledge in contemporary areas of Virology and interdisciplinary areas of microbial sciences.
5. Preparing students to have qualities such as honesty, integrity, carefulness, courage, resilience, self-discipline, openness, innovative thinking and determination to keep going forward, which make them ethically strong and to cotribute to the betterment of society and human kind.

About the Program

The unique M.Sc. Program of Virology at Sri Venkateshwara University College of Sciences (SVUCS), Tirupati started in 1987, iscommitted to achieve excellence in education, research, and extension through systematic and focused teaching and hands-on-practical training in contemporary areas of Virology. The program brings together a variety of researchers as faculty members, who made significant contributions in their specializations and are working together for a common goal of identification, characterization, diagnosis, and management of viruses. The program is strengthened by various research projects, sophisticated instrumentation to conduct advanced research and periodical update of the curriculum. The platform aims at equipping the students with necessary scientific skills for Virology related careers, in research, industry and higher education sectors. The students in this program acquire wide knowledge,

critical thinking skills and experience in conducting advanced strategic research and entrepreneurship in core Virology and other major interdisciplinary areas. The curriculum of M.Sc. Virology programis developed keeping in view of the student centric learning practices, which are entirely outcome-oriented and curiosity-driven. Emphasis will be given to train students in theoretical concepts and practical hands-on experience to face the challenges that are recurrent in the field of Virology and to foster employability, responsibility, and lifelong learning, which is the need of the hour to make India's emergence as a global leader in innovation and manufacturing of pharma and biotech products.

The M.Sc. Virology program curriculum framework focuses on pragmatist approach whereby application of theoretical concepts is taught with substantial coverage of practical and field-based studies. The curriculum is designed to educate the students with the basic and advanced concepts of Virology and other major interdisciplinary disciplines by using modern pedagogical tools and concepts such as e-learning platforms, as well as to promote and develop skills and competencies that have enduring value beyond the classroom. While designing these frameworks, emphasis is given on the objectively measurable teaching-learning outcomes to ensure employability of the students.The Program has two academic years with four semesters. The first semester of the program covers the fundamental concepts of General Microbiology, General Virology, Biological Chemistry and Analytical Techniques and with a foundation course on Human and Professional Ethics-I. In the second semester, the students will explore the basic and advanced concepts of Microbial and Molecular Genetics, Recombinant DNA Technology, Cell Biology and Immunology and Human and Professional Ethics-II. The theoretical and practical knowledge acquired in the basic and advanced aspects of interdisciplinary courses will help the students to understand the various aspects of viruses in the third and fourth semesters, where third semester covers courses such as Plant Virology, Plant Viruses and Diseases and Molecular Virology or Biostatistics and Bioinformatics (Generic elective) and forth semester covers courses such as Animal and Human Virology, Animal and Human Viruses and Diseases and Applied Virology or Tumor Biology and Virology (Generic Elective). Apart from these courses, students will get an opportunity to select one of the open elective courses of other programs offered by different Departments in the University in the third and fourth semesters and the program offers Biology of viruses and their management or Biology of virus vectors and their management in the third semester and Clinical Virology or Emerging Infectious Viral Diseases in the fourth semester as open electives to the students to the other departments. The pragmatic core of the framework has been designed such a way to enable the learners implementing the concepts to address the real-world problems. Above all, this framework is aimed to moldmaster graduates to acquire critical thinking, scientific reasoning, moral ethical reasoning qualification descriptors that are specific outcomes pertinent to the discipline and as responsible Indian citizens who have adequate knowledge and skills in reflective thinking, rational skepticism, scientific temper, digital literacy to contribute for betterment of the society and mankind.

S.V. UNIVERSITY, TIRUPATI:: SVU COLLEGE OF SCIENCES
CBCS Pattern (With effect from 2017)
M.Sc., VIROLOGY

SEMESTER-I

Sl. No.	Course Code	Components of Study	Title of the Course	Contact hours	No. of Credits	IA Marks	End SEM Exam Marks	Total
1	VR-101	Core-Theory	General Microbiology	6	4	20	80	100
2	VR-102	Core-Theory	General Virology	6	4	20	80	100
3	VR-103	Core-Practical	General Microbiology and Virology	6	4	-	-	100
4	VR-104	Core-Practical	Biological Chemistry and Analytical Techniques	6	4	-	-	100
5	VR-105	Compulsory Foundation **(Related to Subject)**	Biological Chemistry and Analytical Techniques	6	4	20	80	100
6	VR-106	Elective Foundation **(Human values and ethics)**	Human values and Professional ethics - I	6	4	20	80	100
		Total		**36**	**24**			**600**

SEMESTER-II

Sl. No.	Course Code	Components of Study	Title of the Course	Contact hours	No. of Credits	IA Marks	End SEM Exam Marks	Total
1	VR-201	Core-Theory	Microbial Genetics and Molecular Biology	6	4	20	80	100
2	VR-202	Core-Theory	Recombinant DNA Technology	6	4	20	80	100
3	VR-203	Core-Practical	Microbial Genetics and Molecular Biology & Recombinant DNA	6	4	-	-	100

			Technology					
4	VR-204	Core-Practical	Cell biology and Immunology	6	4	-	-	100
5	VR-205	Compulsory Foundation **(Related to Subject)**	Cell biology and Immunology	6	4	20	80	100
6	VR-206	Elective Foundation **(Human values and ethics)**	Human values and Professional ethics - II	6	4	20	80	100
		Total		**36**	**24**			**600**

SEMESTER-III

	Course Code	**Components of Study**	**Title of the Course**	**No. of Credits**	**IA Marks**	**End SEM Exam Marks**	**Total**
1	VR-301	Core-Theory	Plant Virology	4	20	80	100
2	VR-302	Core-Theory	Plant Viruses and Diseases	4	20	80	100
3	VR-303	Core-Practical	Plant Virology or Plant Viruses and Diseases	4	-	-	100
4	VR-304	Core-Practical	a) Molecular Virology (OR) b) Biostatistics and Bioinformatics	4	-	-	100
5	VR-305	Generic Elective* **(Related to subject)**	(a) Molecular Virology (OR) (b) Biostatistics and Bioinformatics	4	20	80	100
6	VR-306	Open Elective* **(For other departments)**	(a) Biology of Viruses and their Management (OR) (b) Biology of Virus Vectors and their Management	4	20	80	100
		Total		**24**			**600**

***Among the Electives a student shall choose one.**

SEMESTER-IV

	Course Code	Components of Study	Title of the Course	No. of Credits	IA Marks	End SEM Exam Marks	Total
1	VR-401	Core-Theory	Animal and Human Virology	4	20	80	100
2	VR-402	Core-Theory	Animal and Human Virus Diseases	4	20	80	100
3	VR-403	Core-Practical	Animal and Human Virology & Virus Diseases	4	-	-	100
4	VR-404	Core-Practical/ Project work	Project work related to Virology (OR) (a) Applied Virology (OR) (b)Tumor Biology and Viruses	4	-	-	100
5	VR-405	Generic Elective* **(Related to subject)**	(a) Applied Virology (OR) (b)Tumor Biology and Viruses	4	20	80	100
6	VR-406	Open Elective* **(For other departments)**	(a) Clinical Virology (OR) (b) Emerging Infectious Viral Diseases	4	20	80	100
		Total		**24**			**600**

***Among the Electives the student shall choose one.**

Program Outcomes (POs)

S. No	Program Outcomes (POs)
PO-1 DisciplinaryKnowledge	Ability to demonstrate understanding, comprehensive knowledge and skills in various methodological and analytical approaches that are used in contemporary areas of Virologywhich will make them eligible for higher studies, jobs in various sectors and entrepreneurship abilities.
PO-2 Communication skills	Ability to express, communicate and share thoughts, scientific concepts and ideas and experimental results clearly, concisely, and effectively, both in writing and orally.
PO-3 Critical thinking and problem solving	Capability to evaluate basic concepts, theories and mechanisms related to Virology based on empirical evidence by following strategic scientific approach to acquire knowledge to find solutions to virus problems related to microbes, plants, animals, and humans.
PO-4	Ability to evaluate the reliability and relevance of evidence, identify

Analytical reasoning	logical flaws in others argument, analyse and synthesize data from a variety of sources; draw valid conclusions with supporting evidences and examples and address opposing viewpoints.
PO-5 **Scientific reasoning and research-related Skills**	Develop ability to review of scientific literature, independently carry out a complete scientific work process, including the understanding of theoretical background, defining, and formulating problems, hypothesis generation, collection, analysis and evaluation of data, and interpretation and presentation of results of an experiment or investigation in the field of Virology.
PO-6 **Collaboration/ Cooperation /Teamwork:**	Demonstrate high competence and multidisciplinary subject experience within selected topics related to Virology as a team member and ability to facilitate cooperative or coordinated effort and to contribute to a multidisciplinary team in the interest of common cause.
PO-7 **Information/Digital literacy**	Ability to use ICT (Information and communication Technology) in a variety of learning situations, demonstrate the ability to access, evaluate and use a variety of relevant information sources and to use appropriate software for analysis of data.
PO-8 **Self-directed learning**	Ability to work independently, identify appropriate resources required for a project and manage a project through to completion.
PO-9 **Usage of modern tools and techniques**	Ability to demonstrate the practical skills in use of appropriate modern tools, advanced technologies and methods and skills necessary for designing and conducting experiment or investigation with an understanding of limitations.
PO-10 **Moral and ethical awareness/reasoning:**	Demonstrate the ability to assess and predict the technological, ethical, and social effects of one's own work /disciplines and of Virology, use ethical practices and avoid unethical behavior such as fabrication, misrepresentation of data or committing plagiarism, not adhering to intellectual property rights, and adopt objective, unbiased and truthful actions in all aspects of work.
PO-11 **Leadership readiness/qualities**	Acquire teamwork abilities and leadership qualities through various activities during their course work and demonstrate capability tomap out the tasks of a team or an organization, and sett direction, formulate an inspiring vision, build a team who can help achieve the vision, motivate, and inspire team members to engage with that vision, and use management skills to guide the team to the right destination in a smooth and efficient way.
PO-12 **Lifelong learning**	Ability to acquire knowledge and skills that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development and adopt to meet the demands of workplace through knowledge/skill development/reskilling.

Program Specific Objectives (PSOs)

After completion of M.Sc. program in Virology, the students will be able to

S. No	Program Specific Objectives (PSOs)
1	Demonstrate comprehensive knowledge and practical skills inthe area of Virologystarting from General Virology, Plant, Animal and Human Virology, Plant, Animal and Human Virus Diseases to advanced Molecular Virology, Applied Virology, Tumor Virology, Clinical Virology, Virus Epidemiology and Disease management, Virus-Host-Vector interactions, Viral Vaccines, Emerging and reemerging Viruses, Virus-based Bio-nanotechnologythat are relevant and required to create employment opportunities like Faculty/Scientists in academia and industrial jobs like Pharmaceuticals and Biotech-based companies.
2	Develop knowledge and transferable skills in the fields of Biological Chemistry, Analytical Techniques, General Microbiology, Cell and Molecular Biology, Recombinant DNA Technology, and Immunology with an introduction to Biostatistics and Bioinformatics to facilitate interdisciplinary research, which facilitates the participation and qualification in competitive examinations like GATE, UGC-CSIR-NET, APSET, GRE and Civil services.
3	Use knowledge and skills required for identifying problems and issues, collection of relevant quantitative and/or qualitative data, designing strategies for identification, characterization of important, emerging, and reemerging virus pathogens infecting microbes, plants, animals, and humansand for promoting collaborative linkages with industries and research organizations for knowledge exchange and possible process/product development.
4	Gain in depth knowledge on the overall virus world and their characteristics such as history, origin, classification, nomenclature, etiology, structure, genome organization, transmission, multiplication, pathogenesis, epidemiology, strains, diagnosis and management of pathogenic viruses, which will help to design and develop affordable point of care diagnostics, novel prophylactic and therapeutic interventions to combat the infections caused by harmful viruses of microbes, plants, animals and humans.
5	Get exposure to open elective courses such as Tissue Culture, Mushroom Cultivation, Industrial Microbiology, Psychology, Aquaculture and Fishery Sciences, Medicinal and Ethno Botany, Hydroponics, Herbal drugs, Food and Nutrition etc., which will open new avenues and employment opportunities.
6	Acquire knowledge on human and professional ethical practices and principles,responsibilities and norms that need to be followed in personal and professional lifeto contribute to the welfare of the society and mankind.

SEMESTER-I

VR-101: GENERAL MICROBIOLOGY (Core-1)

Lecture: 5 hours/week	**Internal test Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: I	**Credits: 4 Credits**

Course Educational Objectives:

1. To learn aboutfundamentals aspects of microbiology including origin, evolution ofmicroorganisms, different groups of microorganisms and their importance, microscopy principles and applications, morphology, and structure of bacteria,
2. To learn about Microbiological media, isolation, cultivation and enumeration methods of microorganisms, microbial growth characteristics, maintenance, and preservation of microbial cultures.

3. To develop knowledge on microbial taxonomy, transport of nutrients in microbes, control strategies of microorganism,

4. To develop knowledge on general characteristics, structure and reproduction of fungi, algae, and protozoan parasites.

UNIT – I

Fundamental microbiology: Origin and evolution of microorganisms. Pioneers in microbiology, Branches in microbiology, different groups of microorganisms.An overview on the importance of microorganisms in plants, animal, and human welfare.
Microscopy- principles and applications of light, phase - contrast, dark-field, fluorescent, scanning and transmission electron microscopes. – Microbial staining techniques Preparation of microbiological specimens for microscopy -
Morphology and structure of bacteria- Morphological types - cell walls of Gram negative - Gram positive bacteria - cell wall, antigenic properties - capsule - cell membranes - structure - composition - properties. Structure and function of flagella - cillia - pili. Nucleoid - cell division- endospores, structure, formation and germination.

UNIT-II

Microbiological media: Types of media- natural and synthetic; basal, defined, complex, enrichment, selective, differential, maintenance and transport media.
Isolation, cultivation, and enumeration methods of microorganisms: Isolation /enumeration methods from different natural samples. Streak plate, pour plate, spread plate and hanging drop methods, Pure cultures techniques for microorganism.
Microbial growth: Definition, Microbial growth curve, Batch culturing, Continuous, synchronous, Biphasic culturing, generation time, factors influencing the growth, physical chemical and biological, Microbial growth measurement methods.
Maintenance and preservation of microbial cultures: Short-term and long term preservation methods:Repeated sub-culturing, oil overlay, sterile soil/sand, glycerol-deep freezing, drying methods, freeze-drying. Revival of bacterial cultures.

UNIT-III

Microbial Taxonomy: General criteria for microbial classification- Hackel's three kingdom concept - Whittaker's five kingdom concept - three domain concept of Carl Woese. General characteristics of Archaea evolutionary significance. General characteristics of Spirochetes, Rickettsias, Actinomycetes, Cyanobacteria,

Transport of nutrients in microbes- structural organization of plasma membrane in relation to transport, types and mechanisms of transport (passive, simple, facilitated, active) chemical modification methods for studying of transport, coupling of transport of ions and metabolites to ATP/proton gradient.

Control of Microorganism:Physical agents: Heat, radiation, pH, Surface tension, osmotic pressure, filters, **Chemical agents**, Acids, Bases, Alcohols, Aldehydes,Ketones, Phenols, Soaps, Antibiotics, secondary metabolites, Antiseptics.

UNIT-IV

Eukaryotic microorganisms (Fungi, Algae and Protozoan parasites) :

Fungi: General characteristics structure and reproduction and importance of fungi-*Saccharomyces*, Pichia,*Pencillium*, *Rhizopus*, *Aspergillus*, *Trichoderma*,

Algae: General characteristics, structure, reproduction of algae*Chlorella,* and *Gracellaria*. Economic importance of algae.

Protozoan parasites: General characteristics, morphology and structure, reproduction of pathogenic protozoan parasites Entamoeba, *Plasmodium*, *Leishmania*,

Course Outcomes: At the end of the course the student will be able to

CO1: Understand the origin, evolution, different groups and importance of microorganisms and learn the types, principles and applications of microscopy, morphology, and structure of bacteria.

CO2: Learn the basic concepts of media preparation, isolation, cultivation, enumeration, growth measurement, maintenance, and preservation methods of microorganisms.

CO3: Explain the general criteria for microbial classification, general characteristics of microorganisms, mechanism of nutrient transport in microbes and strategies used for control of microorganisms.

CO4: Describe the general characteristics, structure, reproduction of important fungi, algae and protozoan parasites and learn the concepts of bioenergetics and biosynthesis of carbohydrate, lipid, carbohydrates, and proteinsand use this knowledge to compete for UGC-CSIR-NET, GATE, APSET and other scientific examinations.

Suggested Books:

1. Brock Biology of Microorganisms. 1997, 8th ed. Madigan et al., Prentice-Hall International, Inc.
2. Microbiology. 1999. 3rd ed. Prescott et al. Wm. C. Brown Publ.

3. Principles of Microbiology. 1997. 2nd ed. R.M. Atlas. Wm.C. Brown. Publ.
4. Foundations in Microbiology. 1996. 2nd ed. K. Talaro and A. Talaro. Wm.C. Brown Publ.
5. Microbiology. 1996. 5th ed. Pelczar et al. Tata McGraw-Hill Publ. Company Ltd.
6. General Microbiology, 1999 by S.B. Sullia, Oxford and IBH Publishers.
7. General Microbiology, 1999 by Stainer et al., Macmillan Educational Ltd.
8. Instant Notes in Microbiology. 1999. J. Nicklin et al. Viva Books Pvt. Ltd.
9. Microorganisms, Biotechnology and Disease: Students Book. 1997 by Pauline Lourie and Susanwells. Cambridge University Press.
10. Introductory Mycology. 1996. 4th ed. Alexopoulos et al., John Wiley and Sons.
11. Introductory Phycology by H.D. Kumar. 2nd ed. 1999. East-West Press.
12. Biology of the prokaryotes. 1998. By J.L. Lengeler et al., Blackwell Science Publ.
13. Microbiology, 8th Edition International Student Version Jacquelyn G. Black (Marymount University) April 2012, ©2011, Wiley publication.
14. Understanding Microbes: An Introduction to a Small World Jeremy W. Dale December 2012, Wiley-Blackwell
15. Brock Biology of Microorganisms :Global Edition, 13th Edition, Michael Madigan, John Martinko, David Stahl, David Clark Apr 2011.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	2	1	1	3
CO2	3	3	3	3	2	3	2	2	2	2	1	2
CO3	2	2	2	2	1	3	3	2	2	2	1	2
CO4	1	1	1	-	-	3	3	1	2	1	-	1

VR-102:GENERAL VIROLOGY (Core Theory)

Lecture: 5 hour2s/week	**Internal test Assessment: 20 Marks** **Seminars and assignments**
Tutorial:Textboo1ks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: I	**Credits: 4 Credits**

Course Educational Objectives:

1.To understand the history, properties, nomenclature and classification of viruses and development of virology and

2. To learn about methods used for isolation, cultivation, and purification of viruses.

3..To acquire knowledge about the methods used for quantitation of viruses and major characteristics of important plant and animal virus families and biology and applications of major RNA and DNA viruses of insects,

4. To acquire knowledge about bacteriophages, algal and fungal viruses, subviral agents, importance of viruses in human welfare.

UNIT-I

History: Discovery of viruses and development of Virology (contributions of pioneers). Nature, origin and evolution of viruses.
Properties of viruses: Physical- morphology and structure, sedimentation, electrophoretic mobility, buoyant density. Biochemical- chemical composition, nucleic acids, proteins, enzymes, lipids, carbohydrates, polyamines, cations.Antigenic nature of viruses. Biological- host range, transmission (vector and non-vector), virus stability.
Nomenclature and classification of viruses: Criteria used for naming and classification. Current ICTV classification of viruses of bacteria, plants and animals and humans.

UNIT-II

Isolation, cultivation, assay and maintenance of bacterial, plant and animal viruses: Experimental plants and tissue cultures. Experimental animals, embryonated eggs, organ cultures, primary and secondary cell cultures, suspension and monolayer cell cultures, cell strains, cell lines.
Purification of viruses: Need for virus purification. Extraction of viruses from tissues, clarification, concentration of viruses in clarified extracts by physical and chemical methods, further purification of viruses by rate zonal / equilibrium density gradient centrifugation.Criteria of virus purity.Quantitation and preservation of purified virus preparations.

UNIT-III

Quantitation of viruses: Infectivity assay methods (plaque, pock, end point, local / systemic assay of plant viruses), physical (EM), serological (HA, HI, immunofluorescence, ELISA) and chemical (viral protein and nucleic acid based) approaches.
Major characteristics of the following virus families / genera / groups:
Adenoviridae, Bromoviridae, Bunyaviridae, Caulimoviridae, Flaviviridae, Geminiviridae, Hepadnaviridae, Herpesviridae, Orthomyxoviridae, Paramyxoviridae, Parvoviridae, Picornaviridae, Potyviridae, Poxviridae, Reoviridae, Retroviridae, Rhabdoviridae, Tobamovirus,
Insect Viruses: Biology of major RNA and DNA viruses of insects and their applications

UNIT-IV

Bacteriophages: Biology of major RNA (MS_2, Qβ, Ø6) and DNA (T-even and T-odd, lambda, Mu, Øx174, M_{13}) bacteriophages. Biology of Cyanophages.
Algal and fungal viruses: Biology of viruses of *Phycodnaviridae*, *Partitiviridae*and *Totiviridae*.
Biology of sub-viral agents: Satellite viruses, sat-RNAs, viroids virusoids and prions. Concept of molecular parasitism.
Importance of viruses in human welfare with suitable examples.

Course Outcomes: At the end of the course the student will be able to

CO1: Learn the discovery, nature, origin and evolution of viruses and the physical, biochemical, and biological properties of viruses, criteria used for nomenclature and classification of bacteria, plant and animal viruses.

CO2:Describe the methods used for isolation, cultivation, and purification of viruses and criteria of purity.

CO3: Definebiological, physical, biochemical, and serological methods used for quantitation of viruses, major characteristics of important plant and animal virus families and biology and applications of major RNA and DNA viruses of insects.

CO4: Understand thebiology of major bacteriophages, algal and fungal viruses, subviral agents and importance of viruses in human welfare with suitable examples.

Suggested Books:

1. Virology: Principles and Applications: John B CarterReviews, John Wiley & Sons, Limited, 08-Mar-2013 - 400 page
2. Virology: 1994. 3rd ed. Frankel-Conrat et al, Prentice- Hall.
3. Principles of Virology: 2000. by S.J. Flint et al., ASM Press.
4. Introduction to Modern Virology. 2001. 5th ed. Dimmock et al., Blackwell Sci. Publ. Principles of Molecular Virology. 1997. 2nd ed. A. Cann. Academic Press.
5. Basic Virology, 1999. By Waginer and Hewelett, Black Well Science Publ.
6. Medical Virology. 1994. 4th edition. D.O. White and F.J. Fenner. Academic Press. Plant Virology. 2001. 4thedi. By R. Hull. Academic Press.
7. Fundamental Virology, 4th ed. 2001. D.M. Knipe and P.M. Howley.
8. Veterinary Virology. 3rd ed. 1999. Murphy et al., Academic Press.
9. Arora, P.N. Sumeet Arora & S. Arora (2007). Comprehensive Statistical Methods. S. Chand & Company, New Delhi.
10. Misra, B.N. & M.K. Misra (1998). Introductory Practical Biostatistics. Naya Prakash, Kolkata.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2	3	3	3	3	2	1	2	3
CO2	3	3	3	3	2	3	2	2	2	2	2	1
CO3	2	2	2	2	1	3	3	2	2	2	1	1
CO4	1	1	1	-	-	3	3	1	2	1	-	1

VR-103: PRACTICAL: GENERAL MICROBIOLOGY AND VIROLOGY (Core-3)

Lecture: 9 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Lab manuals, E-learning resources, textbooks and study	

materials	
Semester: I	**Credits: 4 Credits**

Course Educational Objectives:

1. To learn the safety measures in handling different types of microorganisms and to practice various methods used for isolation, cultivation, and identification of the microorganisms from different sources and checking growth parameters at various conditions.

2. To demonstrate the practical skills in isolation of bacteriophages, cultivation of viruses in embryonated eggs and plants, transmission of plant viruses and checking the stability of plant viruses.

List of Practicals:

1. Microbiological laboratory safety measures
2. Sterilization Methods
3. Phenol coefficient method
4. Preparation of media for cultivation of bacteria, fungi and actinomycetes
5. Enumeration of bacteria, actinomycetes and fungi from soil
6. Plating techniques- streak plate, pour and spread plate methods
7. Microbiological staining techniques: Simple staining , Gram staining , Spore staining
8. Lactophenol-cotton blue staining for fungi
9. Hanging drop method for bacterial motility
10. Determination of Bacterial growth curve
11. Effect of pH on bacterial growth
12. Effect of temperature on bacterial growth
13. Effect of salt concentration on bacterial growth
14. Oligodynamic action of heavy metals and antibiotics
15. Isolation of bacteriophages from sewage water
16. Cultivation of viruses in embryonated Eggs: different routes of inoculation.
17. Sap, Aphid and Graft transmission of a plant viruses.
18. Virus inclusion bodies (slides)
19. Determination of stability of plant virus in cell sap- TIP, DEP, LIV.
20. Determination of chlorophylls in healthy and virus diseased leaves.

Course Outcomes: At the end of the course the student will be able to

CO1: Define laboratory safety measures that needs to be followed in Virology and Microbiology laboratories and know the concepts and protocols of using different sterilization methods and preparation of media.

CO2: Acquire the practical skills to use various methods for cultivation, staining and characterization of different microorganisms and to check their stability under various conditions.

CO3: Learn to isolate bacteriophages from different sources and cultivate viruses in embryonated eggs and plants.

CO4: Demonstrate the mechanical, aphid and graft transmission of plant viruses and methods used to check the stability of viruses and determine the effect of virus infection on plants through chlorophyll estimation.

Suggested Books / Manuals:

1. Diagnostic Microbiology. 11th Edition. 2002. By B.A. Forbes et al., Mosby publisher
2. Practical Microbiology, 2002 by R.C. Dubey and D.K. Maheshwari.
3. Laboratory Manual in Microbiology, 2000. By P. Gunasekaran
4. Virology - A Laboratory Manual, 1992. By Burleson, et al., Academic Press.
5. Virology Methods Manual, 1996. B.W.J. Mahy and H.O. Kangro. Academic Press
6. Molecular Virology: A Practical Approach. 1993. Davison and R.M. Elliot. Oxford University Press.
7. Virology Lab Fax. 1993. D.R. Harper. Bioscientific Publication. Academic Press
8. Microbiological Applications: Laboratory Manual in General Microbiology, 7th ed. by J. Benson.
9. Microbiology: A Laboratory Manual. 4th edition. By J.G. Cappuccino and N. Sherman.
10. Experiments in Microbiology, Plant Pathology, Tissue culture and Mushroom cultivation. 3rd edition.By K.R. Aneja.
11. Laboratory Experiments in Microbiology by Johnson.
12. Laboratory Manual in Microbiology by Alcamo.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**2**	**3**	**2**	**3**	**3**	**2**	**1**	**1**	**3**
CO2	**3**	**3**	**3**	**3**	**1**	**3**	**2**	**2**	**2**	**2**	**2**	**1**
CO3	**2**	**2**	**2**	**2**	**1**	**3**	**3**	**2**	**2**	**2**	**1**	**-**
CO4	**1**	**1**	**1**	**-**	**-**	**3**	**3**	**1**	**2**	**1**	**-**	**1**

VR-104: PRACTICAL: BIOLOGICAL CHEMISTRY AND ANALYTICAL TECHNIQUES (Core-4)

Lecture: 9 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Lab manuals, E-learning resources, textbooks and study materials	
Semester: I	**Credits: 4 Credits**

Course Educational Objectives:

1. To estimate carbohydrates, nucleic acids, amino acids, proteins, glucose, bilirubin, and inorganic phosphorus using qualitative and quantitative tests and to determine the activity of enzymes.

2. To acquire hands-on experience in using various analytical tools such as ultrafiltration, electrophoresis, spectroscopy, chromatography and centrifugation techniques for the isolation and characterization of biomolecules isolated from various sources.

1. Qualitative tests for identification of Carbohydrates, amino acids, nucleic acids
2. Quantitative determination of Protein, glucose, glycine, bilirubin, cholesterol, Inorganic phosphorous
3. Determination of activity of peroxidase and polyphenol oxidase from leaves
4. Measurement of pH
5. Micrometry for cell size determination
6. Cell counting by Haemocytometer.
7. Verification of Beer's Law
8. Determination of λ max for colored solutions
9. Determination of DNA & RNA by UV spectrophotometry
10. Determination of nucleic acid Bases by UV spectrometry
11. Paper chromatography for separation of amino acids / pigments
12. TLC for separation of lipids / amino acids.
13. Dialysis of different samples.
14. SDS-PAGE for separation of proteins
15. Submarine agarose gel electrophoresis for DNA separation
16. Isolation of chloroplasts by sucrose density gradient centrifugation
17. Concentration of biomolecules by flash evaporation / freeze-drying.
18. Separation of amino acids by ion-exchange column chromatography
19. Gel permeation column chromatography (demonstration).
20. Spun column chromatography (demonstration).

Course Outcomes: At the end of the course the student will be able to

CO1: Learn to calculate normality, molarity, molecular weight and percentage of chemical substances and qualitative and quantitative estimation of proteins, carbohydrates, lipids, and nucleic acids.

CO2: Know how to isolate and check the activity of enzymes from various sources.

CO3: Learn to use ultrafiltration, chromatography, and electrophoresis techniques for isolation and characterization of biomolecules.

CO4: Acquire the skills to use spectroscopic and centrifugal methods for isolation and characterization of biomoleculesapply this practical oriented knowledge in Cell Biology and Immunology to foster employability in private industries, higher education in premier institutes.
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Suggested books:

1. Microbiology Tools & Techniques -2008-Kanika Sharma-Ane books, India.
2. Protein Purification Techniques 2nd ed.-2001-Simon Roe-Oxford University Press
3. Introduction to Practical Biochemistry. 2000. by S.K.Sawhney and Randhir Singh (eds.) Narosa Publ. House
4. Laboratory Manual in Biochemistry, 1996. By J. Jayaraman.
5. Practical Biochemistry: Principles and Techniques 1995, 4th ed. by K. Wilson and J.Walker, Cambridge University Press.
6. Modern Experimental Biochemistry. 1993. 2nd ed. by R.F. Boyer. The Benjamin Cummings Publ. Company.
7. Biochemical Methods per Agricultural Sciences, 1992. By S. Sadasivam and A. Manikam.
8. Physical Biochemistry: Applications to Biochemistry and Molecular Biology, 1982, 2nd ed. by David Freifelder. W.H. Freeman and Company.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	2	1	2	3
CO2	3	3	3	-	-	3	2	2	2	1	-	-
CO3	2	2	2	2	1	3	3	2	2	2	1	2
CO4	1	1	1	2	2	3	3	1	2	2	1	1

VR-105: BIOLOGICAL CHEMISTRY AND ANALYTICAL TECHNIQUES

(Compulsory Foundation)

Lecture: 5 hours/week	**Internal test Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: I	**Credits: 4 Credits**

Course Educational Objectives:

1. To learn the basic concepts of chemistry of life, bioenergetics, chemical processes of living organisms and the classification, structure, properties and functions of biomolecules of life (carbohydrates, nucleic acids, amino acids, peptides, proteins and lipids) and mechanism of protein metabolism and to understand the properties,
2. To learn the basic concepts of biological functions of enzymes, nucleic acids, hormones, growth regulators, vitamins, porphyrins and other pigments and nucleic acid metabolism.

3. To describe the approaches involved in characterization and concentration of biomolecules and to train students in adopting various techniques involved in biological research such as chromatography, centrifugation, electrophoresis

4. To learn about electrochemical techniques, basic principles and applications of flow cytometry, radioisotopes, spectroscopy, amino acid and nucleotide sequencers.

UNIT-I

An overview on basic concepts of Chemistry of life: The major elements of life and their primary characteristics; atomic bonds and molecules - bonding properties of carbon, covalent and non-covalent bonds.
Bioenergetics: Concepts of free energy and thermodynamic principles in biology, energy transformation, ATP cycle, energy transducers, redox potentials, free energy changes in redox reactions.
Carbohydrates: Classification, structure and properties of carbohydrates; biological importance of polysaccharides; Carbohydrate metabolism- Pathways underlying the utilization of different sugars (EMP, ED, HMP and phosphoketolase) in microorganisms, gluconeogenesis.
Lipids: Fatty acids- physico-chemical properties; Classification, outline structures, properties and functions of lipids; Lipid metabolism- Biosynthesis of triacyl glycerols; oxidation of saturated and unsaturated fatty acids
Amino acids: Classification, structures, functions, physico-chemical properties.
Peptides: peptide bond, properties and functions of peptides,
Proteins: Classification, properties and biological functions of proteins; structural organization of proteins - primary, secondary, tertiary and quaternary with examples; Ramachandran's plot; chaperones.
Protein metabolism: Hydrolysis of proteins-exo- and endo-proteinases, outlines of biosynthesis and catabolism of amino acids in microbes (deamination, decarboxylation and transamination reactions); Urea cycle.

UNIT-II

Catalytic proteins (enzymes): Classification, nomenclature, composition and structures, enzymes as biocatalysts, outlines of purification and assay of enzymes, kinetics of enzyme catalyzed reactions, factors influencing enzyme catalyzed reactions, regulation of enzyme activity; Isoenzymes, coenzymes, ribozymes, abzymes.
Nucleic acids: types and their composition, structures of purines, pyrimidines, modified bases, nucleosides, nucleotides and polynucleotides; properties of bases and functions of nucleotides; types and structural polymorphism of DNA and RNA; denaturation and renaturation of nucleic acids, factors influencing hybridization, cot values.
Nucleotide metabolism: Biosynthesis of bases, nucleosides and nucleotides including deoxyribonucleotides, regulation of nucleotide synthesis; exo- and endonucleases (RNases and DNases) and phosphodiestases
Hormones and Growth regulators: Introduction to harmones and growth regulators and their functions.
Vitamins: Introduction, types and functions of vitamins.

Porphyrins and other pigments: Classification, structures and biological functions of porphyrins.

UNIT-III

Characterization of biomolecules: Introduction and various approaches for characterization of biomolecules.
Concentration of biomolecules: Salting out with ammonium sulfate, flash evaporation, lyophilization, dialysis, hallow fiber membranes, membrane filtration and their applications.
Chromatography: Principle, simple theory and applications of partition, adsorption, ion-exchange, gel permeation and affinity chromatography based techniques - paper, thin-layer-TLC, column, GLC, HPLC, FPLC.
Centrifugation: Simple theory of preparative and analytical centrifuges and rotors; sedimentation analysis; differential, rate-zonal and equilibrium density gradient centrifugations; Applications- isolation of cells, subcellular organelles, viruses and macromolecules.
Electrophoresis: Introduction and Principle; types of electrophoresis- paper, gel (starch, acrylamide and agarose), disc, vertical, horizontal submarine, gradient, 2-dimentional, pulse-field and capillary; isoelectric focusing; isolation and analysis of gel separated molecules; southern, northern and western blotting; Applications.

UNIT-IV

Electrochemical techniques: Redox reactions; pH and Clarke oxygen electrodes; biosensors.
Cell sorting and Flow cytometry: Principles and Applications.
Radioisotope techniques: Nature and types of radioactivity, half-life, detection and measurement of radioactivity- GM counter, liquid scintillation counter, gamma-ray counter, Cerenkov counting and autoradiography; quenching and quench correction; laboratory safety measures in handling isotopes; biological uses of radioisotopes.
Spectroscopy: Electromagnetic spectrum of light; simple theory of light absorption by biomolecules; Beers- Lambert law; transmittance; extinction co-efficient; light sources; monochromators; types of detectors; working principle and applications of visible, UV-visible, IR, Raman, ESR, mass, MALDI, plasma emission, atomic absorption, and NMR spectrophotometry; fluorimetry and flame photometry; ORD and CD; X-ray diffraction and X-ray crystallography, Microarray.
Amino acid and nucleotide sequencers: Basic principles of functioning and applications.

Course Outcomes: At the end of the course the student will be able to

CO1: Acquire knowledge on major elements and biomolecules of life and their chemical composition, bonding and primary characteristics, classification, structure, functions of carbohydrates, nucleic acids, amino acids, peptides, proteins and lipids and mechanism of protein synthesis and degradation.

CO2: Understand the types, properties, biological functions of enzymes, nucleic acids, hormones, growth regulators, vitamins, porphyrins and other pigments and nucleic acid metabolism.

CO3: Describe the approaches involved in characterization and concentration of biomolecules and discuss the principles and applications of various techniques applied for characterization of biomolecules in biological research such as chromatography, centrifugation, electrophoresis,

CO4: Learn about electrochemical techniques, basic principles and applications of flow cytometry, radioisotopes, spectroscopy, amino acid, and nucleotide sequencers.

Suggested Books:

1. Principles of Biochemistry, Lehninger, 3rd edition by Nelson and Cox (Worth) 2000.
2. Biochemistry, Stryer 5th edition, W.H. Freeman, 2001.
3. Microbial Physiology and Metabolism. 1995, by D.R. Caldwell. Wm.C. Brown Publ.
4. Microbial Physiology. 1999, 3rd ed. by A.G. Moat & J.W. Foster. Wiley- Liss.
5. Foundations in Microbiology. 1996. By K. Talaro& A. Talaro, Wm. C. Brown Publ.
6. Microbial Physiology and Metabolism. 1995, by D.R. Caldwell. Wm.C. Brown Publ.
7. Microbial Physiology. 1999, 3rd ed. by A.G. Moat & J.W. Foster. Wiley- Liss.
8. Foundations in Microbiology. 1996. By K. Talaro& A. Talaro, Wm. C. Brown Publ.
9. Molecular Cell Biology. 2000 - by Lodish et al.
10. Textbook of Biochemistry, by Voet and Voet.
11. Practical Biochemistry: Principles and Techniques 1995, 4th ed. by K. Wilson and J.Walker, Cambridge University Press.
12. Modern Experimental Biochemistry. 1993. 2nd ed. by R.F. Boyer. The Benjamin Cummings Publ. Company.
13. Physical Biochemistry: Applications to Biochemistry and Molecular Biology, 1982, 2nd ed. by David Freifelder. W.H. Freeman and Company.
14. Introduction to Practical Biochemistry. 2000. by S.K. Sawhney and Randhir Singh (eds.) Narosa Publ. House
15. Biochemical Methods for Agricultural Sciences. 1992 by S. Sadasivam and A. Manikam. Wiley Eastern Ltd.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**2**	**2**	**3**	**3**	**3**	**2**	**2**	**3**	**3**
CO2	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**2**	**1**	**2**	**1**	**1**
CO3	**2**	**2**	**2**	**-**	**1**	**3**	**3**	**2**	**2**	**1**	**1**	**2**
CO4	**1**	**1**	**1**	**2**	**-**	**3**	**3**	**1**	**2**	**2**	**-**	**1**

VR-106: HUMAN VALUES AND PROFESSIONAL ETHICS– I (Elective Foundation)

Lecture: 4 hours/week	**Internal test Assessment: 20 Marks**
Tutorial: Textbooks, E-learning	**Semester End Examination: 80 Marks**

resources, study materials, PowerPoint lectures	
Semester: I	**Credits: 4 Credits**

Course Educational Objectives:

1.To enable the students to imbibe and internalize the moral and social values

2.To enable the students ethical behavior in the personal and Professional lives.

3. To learn the rights and responsibilities

4.To appreciate the rights of others and to create awareness on religious values and other good acts and facts of life.

UNIT-I

Definition and Nature of Ethics- Its relation to Religion, Politics, Business, Legal, Medical and Environment.Need for and Importance of Professional Ethics - Goals - Ethical Values in various Professions.

UNIT-II

Nature of Values- Good and Bad, Ends and Means, Actual and potential Values, Objective and Subjective Values, Analysis of basic moral concepts- right, ought, duty, obligation, justice, responsibility and freedom, Good behavior and respect for elders.

UNIT-III

Ahimsa (Non-Violence), Satya (Truth), Brahmacharya (Celibacy), Asteya(Non possession) and Aparigraha(Non- stealing). Purusharthas(Cardinal virtues)-Dharma (Righteousness), Artha(Wealth), Kama(Fulfillment Bodily Desires), Moksha(Liberation).

UNIT-IV

Bhagavad Gita- (a) Niskama karma. (b) Buddhism- The Four Noble Truths - Arya astangamarga, (c) Jainism- mahavratas and anuvratas. Values Embedded in Various Religions, Relirious Tolerance, Gandhian Ethics.

UNIT-V

Crime and Theories of punishment- (a) Reformative, Retributive and Deterrent. (b) Views on manu and Yajnavalkya.

Course Outcomes: At the end of the course the student will be able

CO1:Aware of the moral values and ethical principles ethics for successful personaland professional life.

CO2: Learn the moral values and good behavioral concepts that need to be followed for a better life, learn to respect others, and develop civil sense to act as responsible citizen by developing sufficient knowledge and skills in critical thinking, scientific reasoning, moral ethical reasoning that are pertinent to the discipline

CO3: Acquire the knowledge about the importance of non-violence, truth, righteousness, and other good acts of life and develop commitment.

CO4: Learn to live peacefully by having knowledge about the important facts of Bhagavad Gita, values hidden in religions, religious tolerance and aware ofcrime, and punishment theories.

Learning Resources and Suggested books:

1. John S Mackenjie: A manual of ethics.
2. "The Ethics of Management" by Larue Tone Hosmer, Richard D. Irwin Inc.
3. "Management Ethics - integrity at work' by Joseph A. Petrick and John F. Quinn, Response Books: New Delhi.
4. "Ethics in Management" by S.A. Sherlekar, Himalaya Publishing House.
5. Harold H. Titus: Ethics for Today
6. Maitra, S.K: Hindu Ethics
7. William Lilly: Introduction to Ethics
8. Sinha: A Manual of Ethics
9. Manu: Manu Dharma Sastra or the Institute of Manu: Comprising the Indian System of Duties: Religious and Civil(ed.) G.C.Haughton.
10. Susruta Samhita: Tr.KavirajKunjanlal, KunjalalBrishagratha, Chowkamba Sanskrit series, Vol I,II and III, Varnasi, Vol I OO, 16-20, 21-32 and 74-77 only.
11. Caraka Samhita: Tr. Dr. Ram Karan Sarma and Vaidya Bhagavan Dash, Chowkambha Sanskrit Series office, Varanasi I, II, III Vol I PP 183-191.
12. Ethics, Theory and Contemporary Issues., Barbara Mackinnon, Wadsworth/Thomson Learning, (2001).
13. Analyzing Moral Issues, Judith A. Boss, Mayfield Publishing Company, (1999).
14. An Introduction to Applied Ethics (Ed.) John H. Piet and Ayodhya Prasad, Cosmo Publications.
15. Textbook for Intermediate logic, Ethics and Human Values, board of Intermediate Education & Telugu Academic Hyderabad
16. Sharma I.C Ethical Philosophy of India. Nagin &co Jalandhar.

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3				3	2			3	2		1
CO2	3				3	2			3	2		1
CO3	3				3	2			3	2		1
CO4	3				3	2			3			1

SEMESTER-II
VR-201: MICROBIAL GENETICS AND MOLECULAR BIOLOGY (Core-1)

Lecture: 5 hours/week	**Internal test Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: II	**Credits: 4 Credits**

Course Educational Objectives:

1. To gain understanding ofprokaryotic and eukaryotic genome organization, modern concept of genes, plasmids, mobile genetic elements
2. To learn gene transfer and mapping mechanisms in bacteria, genetics of viruses and requirements and mechanism of DNA replication.
3. To attain knowledge about the mechanism of DNA damage and repair, concept of mutations and their importance, processes involved in transcription,
4. To attain knowledge about the mechanism of translation, regulation of gene expressionand gene silencing mechanisms.

UNIT-I

Genetic notations, conventions and terminology.Evidence for nucleic acids as information carriers. Overview of Mendelian Genetics

Genomes: types, diversity in size, structure and organization in viruses, prokaryotes (nucleoid) and eukaryotes (chromosomes, ploidy, chromatin and nucleosomes). Chloroplast and mitochondrial genomes.Genome complexity and sequence components.

Genes: The modern concept of the genes, gene structure and architecture, types of genes.

Plasmids: detection, types, properties, purification, transfer, replication and curing, significance / importance.

Mobile genetic elements: Prokaryotes - types and structure of bacterial transposons, and molecular mechanism of transposition. Eukaryotes – types and their structure, and molecular mechanism of transposition. Exploitation of transposable elements in genetics.

UNIT-II

Gene transfer mechanisms and gene mapping in bacteria: Natural and artificial transformation. Conjugation and sexduction.Transductions (generalized; abortive, specialized and cotransduction).

Genetic recombination: Requirements for recombination. Molecular models / basis of recombination.

Genetics of viruses- Recombination in bacteriophages-T_2 and fine structure of rII locus of T_4 phage.Eukaryotic viruses - recombination and reassortment, cross- and multiplicity reactivation,

complementation, phenotypic mixing, ploidy, DI particles, transduction of genes by retroviruses, evolution of viruses (influenza, HIV, herpesviruses).
Central dogma theory and flow of genetic information.
Replication / perpetuation of nucleic acids: Concepts, definitions, and strategies / models for replication. Relation between cell cycle and DNA replication.Molecular mechanisms of DNA replication in prokaryotes and eukaryotes. Replication of single stranded DNA. Inhibitors of DNA replication.

UNIT-III

DNA damage and repair: Classes / types of damage. Repair mechanisms – mismatch repair, short patch repair, nucleotide / base excision repair, recombination repair and SOS system.
Mutations: Types, causes and consequences of mutations. Mutagens and their mode of action.Isolation and analysis of bacterial / phage mutants.Importance of mutants in genetic analysis.
Transcription (RNA biosynthesis): Types of RNA and their role. Organization of protein and RNA encoding transcription units and their transcription in prokaryotes and eukaryotes.Types of RNA polymerases. Protein binding sites on DNA - DNA foot printing. Promoters, enhancers, silencers, insulators.Transcription factors and characteristics of DNA binding proteins.Sigma factors.Events of transcription. Maturation and processing of different RNA transcripts- capping, methylation, polyadenylation, splicing, RNA editing and modification of nucleosides in tRNAs. Regulation of transcription.*In vitro* transcription systems.Inhibitors of transcription.

UNIT-IV

Translation (protein biosynthesis) : Genetic code and its elucidation, structure and composition of prokaryotic and eukaryotic ribosomes, structural features of rRNA, mRNA and tRNAs in relation to function, steps of protein biosynthesis (activation of amino acids, initiation, elongation, termination) in prokaryotes and eukaryotes; post-translational modification of proteins and their sorting and targeting; regulation of translation; inhibitors of protein biosynthesis; in vitro translation systems.
Regulation of gene expression: An overview on levels of regulation, terminology and operon concepts, enzyme induction and repression; positive and negative regulation in *E. coli*- lac and ara operons; regulation by attenuation- his and trp operons; antitermination- N protein and nut sites in Lambda phage. Organization and regulation of nif and nod gene expression in bacteria; Gal operon in yeast. Global regulatory responses- heat shock response, stringent response and regulation by small molecules such as cAMP and PPGPP.
Gene silencing mechanisms: Transcriptional and post-transcriptional silencing. RNA silencing and gene regulation.

Course Outcomes: At the end of the course the student will be able to

1. Learn about prokaryotic and eukaryotic genome organization,modern concept of genes, plasmids, mobile genetic elements.

2. Attain knowledge about the mechanism of DNA damage and repair, concept of mutations and their importance, processes involved in transcription, reverse transcription and translation, regulation of gene expression and gene silencing mechanisms.

CO1: Learn the terminology of molecular genetics, distinguish the prokaryotic and eukaryotic genome organization and describe modern concept of genes, plasmids, and mobile genetic elements.

CO2: Understand the gene transfer and mapping mechanisms in bacteria, genetics of viruses and learn about requirements and mechanism of DNA replication.

CO3: Acquire the knowledge about mechanism of DNA damage and repair, concept of mutations and their importance, requirements, and mechanism of transcription.

CO4: Understand the requirements and processes of translation, compare the levels of regulation of gene expression in prokaryotes and eukaryotesand learn about gene silencing mechanisms.

Suggested Books:

1. Concepts of Genetics, Seventh edition -2007, William S. Klug & Michael R. Cummings. Darling Kindergluy.
2. Molecular Biology of the Gene. 4th Edition. 2004. Pearson Education.
3. Molecular Cell Biology. 2003, by Lodish et al., Scientific american books, W.H. Freeman and Company.
4. Molecular Genetics of Bacteria. 2nd Edition, 2003. By S. Snyder and W. Champness. ASM press.
5. DNA Science: A First course. Second editon -2003-David A. Micklosgrag, A. Freyer& David A, Crotty.
6. Bacterial and Bacteriophage Genetics. 4th ed. 2000. By E.A. Birge. Springer.
7. Molecular Biology. 1995, by David Freifelder, Narosa Publ. House.
8. Textbook of Molecular Biology. 1994, by Sivarama Sastry et al, Macmillan India Ltd.
9. Advanced Molecular Biology: A Concise Reference. 1998, by R.M. Twyman. Viva Books Pvt. Ltd.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	2	3	2	2	1	3	3
CO2	3	3	3	3	-	3	2	3	2	2	2	1
CO3	2	2	2	-	1	1	3	2	2	-	1	2
CO4	1	1	1	2	1	3	3	1	2	1	-	1

VR-202 : RECOMBINANT DNA TECHNOLOGY (Core Theory)

Lecture: 5 hours/week	**Internal test Assessment: 20 Marks** **Seminars and Assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: II	**Credits: 4 Credits**

Course Educational Objectives:

1.To learn basic and advanced tools and techniques, approaches and strategies used in gene manipulation in prokaryotic and eukaryotic systems.
2.To learn themajor techniquesand applications of gene manipulation such asDNA sequencingnucleic acid hybridization

3. To understand the strategies used for gene expression in heterologous hosts,proteomics, genomics.

4.To generate knowledge on genetically modified plants and animals and applications/implications of genetic engineering in agriculture, medicine, industry, and biology.

UNIT-1

Scope and importance of recombinant DNA technology
Tools for Recombinant DNA Technology:GeneVectors-Plasmid, transposon, bacteriophage and plant and animal virus-based vectors for manipulation of genes in bacteria, yeast, plant and animal cell systems. **Enzymes**–different nucleases, DNA and RNA polymerases, DNA joining enzymes (ligases, topoisomerase, recombinase) and other nucleic acid modifying enzymes.**Oligonucleotides -** linkers, adaptors, homopolymer tails, primers, promoters, Ori, marker genes. **Source DNA -** genomic DNA, cDNA, PCR products and chemically synthesized oligonucleotides. **Cloning and expression host systems** -Gram positive and negative bacteria, yeast and other fungi, plants and animal cells.
Cutting and joining of DNAmolecules-generation and joining of blunt and sticky ended DNA molecules using linkers, adaptors and homopolymer tails and PCR amplicons

UNIT-II

Techniques for gene manipulation:DNA sequencing -Chemical, dideoxy chain termination, primer walking, automated sequencing and pyrosequencing methods. **Molecular diagnostics: Nucleic acid blotting and hybridization -** Preparation of DNA and RNA probes, hybridization formats, factors influencing hybridization and applications of hybridization-based tests. **PCR**-principles, factors affecting PCR, different types of PCR and their applications and limitations.**DNA profiling** - RFLP, AFLP, RAPD and DNA finger printing and their applications. **Microarray Technology -** DNA microarrays and chips, protein, antibody / antigen arrays - principles and applications.

Site directed mutagenesis and protein engineering: Different approaches for changing genes. Approaches for protein engineering to generate novel enzymes like subtulisin.
Yeast two hybrid system for assaying protein interactions.

UNIT-III

Gene cloning strategies: Construction of genomic DNA and cDNA libraries and different strategies for selection, screening and analysis of recombinants. Recombinogenic engineering.**Gene cloning in bacteria, yeast, plant and animalcells**-construction of cell specific recombinant vectors, introduction of them into targeted cells by different approaches and screening and isolation of recombinant cell clones. **Genomics** - Mapping and sequencing genomes. Comparative genomics of viruses, prokaryotes and eukarotic microbes.**Functional genomics** - transcriptome and gene expression profiling.**Proteomics**- proteome and analysis of protein expression.Introduction to structural and comparative proteomics.**Metabolomics** - introduction to metabolosome and its analysis.

UNIT-IV

Production of recombinant molecules in expression systems: **Bacterial cell system**-Construction of expression vectors. optimization of cloned gene expression. Purification and analysis of generated recombinant molecules.**Yeast cellsystem** - Construction of vectors for overexpression of genes, optimization of generation of recombinant molecules. **Insect cell system** - Overexpression of cloned genes using baculovirus based vectors. **Plant cell system** - high level expression of cloned genes using plant virus based vectors.
Genetic modification of plants to improve agronomic traits like resistance to herbicides pests, pathogens, drought, salt; control of fruit ripening and to improve nutritional quality and crop yields. Transgenic plants as bioreactors. Genetic trait control technology (traitor technology)
Genetic modification of animals like mice, sheep, pig and cow for new /improved traits like body size and milk quantity.Transgenic animals as bioreactors.Gene targeting, gene knock in and knockout and disease models.Gene therapy.
Nanobiotechnology: scope and importance.
Applications and implications of recombinant DNA technology in biology, agriculture, medicine and industry.

Course Outcomes: At the end of the course the student will be able to

CO1: Explain the scope, importance of genetic engineering, basic steps of gene cloning and the role of enzymes, vectors, oligonucleotides, and hosts in gene manipulation and methods of cutting and joining DNA molecules.

CO2:Describe themajor techniquesand applications of gene manipulation such asDNA sequencing, PCR, DNA profiling, nucleic acid hybridization, microarrays, site directed mutagenesis and protein engineering, Yeast two hybrid system for assaying protein interactions**.**

CO3:Discuss the strategies used for construction of genomic DNA and cDNA libraries and gene cloning strategies in bacteria, yeast, plant, and animal cellsand learn the concepts and applications of genomics, proteomics, transcriptomics, and introduction to metabolomics.

CO4:Understand the basic and advanced concepts of gene expression in prokaryotic and eukaryotic systems, genetically modified plants and animals, learn the scope and importance of nanobiotechnology andanalyze the applications and implications of genetic engineering.

Learning Resources and Suggested books:

1. Principles of Gene Manipulation and Genomics. Seventh edition -2008, S.B. Primrose and R.M. Twyman. Blackwell pub.
2. Recombinant DNA Genes and Genomes: A Short course. Third edition -2007 James D. Watson, Amy A. Caudy, Richard M. Mayes & Jan A. Witkow.
3. Gene Cloning and DNA Analysis – An Introduction. Fifth edition-2006. T.A Brown. Blackwell Pub.
4. An introduction to genetic engineering. 2nd edition. 2004. By D.S.T. Nicholl. Cambridge University Press.
5. DNA Science: A First course. Second edition -2003-David A. Micklosgrag, A. Freyer& David A, Crotty.
6. Principles of genome analysis and genomics. 2003. 3rd edition. S.B. Primrose and R.M.Twyman. Blackwell Science.
7. Prokaryotic genomics. 2003. Michel Blot (Ed). Springer International.
8. Recombinant DNA and biotechnology: A guide for Teachers: 2nd ed. H. Kreuzer and A. Massey. ASM Press.
9. Recombinant DNA and biotechnology: A guide to students: 2nd ed. H. Kreuzer and A. Massey. ASM Press.
10. Molecular biology and Biotechnology. 2002. 4th ed. ed. by J.M. Walker and R. Rapley, Panima.
11. Basic Biotechnology, 2001. 2nd ed. ed. by C. Ratledge& B. Kristiansen. Cambridge University Press.
12. Principles of Gene Manipulation: An introduction to genetic engineering. 2001. 6th ed. Old and Primrose. Blackwell Scientific Publ.
13. Functional Genomics: A Practical Approach. 2000, by S.P. Hunt and R. Liveey (eds.). Oxford University Press.

Reference Books:

1. Molecular Cloning, 2001. Vol. I-III by Sambrook and Russel, CSH Press.
2. Current Protocols in Molelcular Biology, 2000. Ausbel et al.
3. Genome analysis. 2000. 4 Vols. CSH Press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**2**	**3**	**3**	**2**	**3**	**2**	**2**	**3**	**3**
CO2	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**2**	**2**	**3**	**1**	**1**
CO3	**2**	**2**	**2**	**-**	**-**	**3**	**3**	**2**	**2**	**2**	**2**	**2**
CO4	**1**	**2**	**1**	**`2**	**1**	**3**	**3**	**1**	**2**	**1**	**-**	**-**

VR-203Core Practical-MICROBIAL GENETICS AND MOLECULAR BIOLOGY & RECOMBINANT DNA TECHNOLOGY

Lecture: 9 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Textbooks, E-learning resources, Lab manuals	
Semester: II	**Credits: 4 Credits**

Course Educational Objectives:

1. To learn laboratory safety practices to be followed to set up Cell and Molecular Biology laboratories and to set up ribonuclease free environment in the laboratories and to acquire the practical skills in conducting various experiments related to Cell Biology such as isolation and estimation of DNA and RNA from microbial, plant and animal sources and to practice Ames test, plasmid curing, replica plate and gradient plate techniques.

2. To acquire practical skills in conducting plasmid isolation, PCR, recovery of DNA, restriction enzyme digestion of DNA, transformation of bacteria with recombinant plasmid DNA, preparation of southern blots and dot-blots for hybridization and to discuss the problems related to Molecular Biology and Recombinant DNA Technology and to learn the basic bioinformatics tools for DNA/protein analysis.

List of Practicals:

1. Creating of ribonuclease free environment in the laboratory.
2. Preparation of phenol for nucleic acid isolation.
3. Concentration of nucleic acids.
4. Isolation of microbial DNA and RNA.
5. Curing of plasmids.
6. Demonstration of Ames test.
7. Replica plating techniques.
8. Demonstration of conjugation in bacteria.
9. Transformation of bacteria.
10. Isolation of microbial mutants by gradient plate method.
11. Induction of mutations in Bacteria by physical / chemical agents.
12. Observation of mitotic divisions in onion root tips and meiotic divisions in onion flower buds.
13. Problems related to microbial molecular biology and genetics.
14. Isolation of plasmids from bacteria.
15. Restriction enzyme analysis of plasmids.
16. Recovery of DNA from gels - Electroelution and extraction of DNA from low melting agarose gels.
17. Southern blotting.
18. Electroblot immunoassay.

19. Preparation of dot-blots for hybridization.
20. Preparation of competent bacterial cells and transformation with recombinant. Plasmid DNA, identification of positive clones by different approaches.
21. Problems related to recombinant DNA technology.

Course Outcomes: At the end of the course the student will be able to

CO1: Learn the safety practices and precautions to be followed in setting up Cell and Molecular Biology laboratory with ribonuclease free environment.

CO2: Isolate and estimate DNA and RNA from microbial, plant and animal tissues and demonstrate curing of plasmids.replica plating techniques, conjugation in bacteria, Ames test, induction of mutations in bacteria by physical/chemical agents, isolation of microbial mutants by gradient plate method.

CO3:Acquire practical skills to isolate plasmids from bacteria, restriction enzyme digestion of recombinant plasmid DNA, recovery of DNA from gels, transformation of bacteria and demonstrate the preparation of southern and dot blots for hybridization.

CO4: Solve the problems related toMolecular Genetics/Biology and Recombinant DNA Technology and compete for the competitive exams such as UGC-CSIR-NET, GATE, APSET and other scientific examinations.

Suggested books:

1. Biotechnology: DNA to Protein: A laboratory project in molecular biology. 2002. T. Thiel, S. Bissen, E.M. Lyons. Tata McGraw-Hill publishing company.
2. Molecular cloning- A laboratory manual. 2001. I, II, III Vols. By Russell and Sambrook. CSH Publs.
3. Methods in Biotechnology. 2001. By Ignacimuthu.
4. Biotechnology: A Laboratory Course. 1996. 2nd ed. J.M. Becker, et al., Acad. Press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**3**	**2**	**3**	**2**	**3**
CO2	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**1**	**-**	**1**
CO3	**2**	**2**	**2**	**2**	**-**	**3**	**3**	**2**	**2**	**-**	**2**	**-**
CO4	**1**	**1**	**1**	**2**	**1**	**2**	**3**	**1**	**2**	**1**	**-**	**1**

VR-204: CORE PRACTICAL – CELL BIOLOGY AND IMMUNOLOGY

Lecture: 9 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Textbooks, E-learning resources, Lab manuals	
Semester: II	**Credits: 4 Credits**

Course Educational Objectives:

1. To acquire the practical skills in conducting various experiments related to Cell Biology such as isolation of cells, preparation of cell and tissue cultures, isolation of mitochondria, study of chromosomes and identification of stages of mitosis in onion root tips.

2.To determine the number of WBC and RBC, estimation of hemoglobin, blood group and Rh typing and to conduct theory exercises on production, purification and analysis of polyclonal antibodies and identification of primary and secondary lymphoid organsvirtually and to perform *in vitro* serological tests such as immune diffusion, immune-electrophoresis, ELISA and western blotting.

List of Practicals:

1. Preparation of cytological studies for identification of stages of mitosis using root tips
2. Examination of cells isolated from chick epithelium.
3. Demonstration of chromosomal (structural and numerical) aberrations.
4. Study of polytene chromosomes.
5. Isolation of mitochondria by density gradient centrifugation.
6. Karyotypic study.
7. Culturing of Sheep kidney cells.
8. Culturing of Chicken embryo fibroblast cells.
9. Sub-culturing of Sheep kidney cells
10. Total counting of RBC & WBC
11. Differential count of W.B.C
12. Haemoglobin estimation.
13. Blood group typing & Rh determination.
14. Latex agglutination test for HBV.
15. Primary & Secondary lymphoid organs.
16. Production of polyclonal antibodies- demonstration of different routes of antigen inoculation, bleeding of experimental animals, and collection of serum.
17. Purification of immunoglobulins.
18. In vitro serological tests: Single & Double immunodiffusion tests; HA & HI tests; Immuno electrophoresis; counter current&rocket electrophoresis; DAC- ELISA (indirect).

Course Outcomes: At the end of the course the student will be able to

CO1: Acquire the practical skills in conducting various experiments related to Cell Biology such as isolation of cells, preparation of cell cultures.

CO2: Learn isolation of mitochondria, study of chromosomes, identification of stages of mitosis in onion root tips.

CO3: Identify of primary and secondary lymphoid organs in virtual animal model andillustrate basic immunology techniques such as counting of RBC and WBC, estimation of hemoglobin, identification of the blood groups and Rh.

CO4:Demonstrate antigen-antibody interactions by conducting *in vitro* serological tests such as immunodiffusion and immune-electrophoresis, DAC-ELISA, Dot-ELISA and western blottingand apply this practical oriented knowledge in Cell Biology and Immunology to foster employability in private industries, higher education in premier institutes.

Suggested books/Manuals:

1. Culture of Animal Cells: A Manual of Basic Technique. 1987. R.I. Freshney. Alan R. Liss Inc.
2. Plant tissue culture:Theory and Practice, 1996.S.S.Bhojwani and M.K.Razdan, Elseiver Pub.
3. Immunology: A Laboratory ManualSpiral-bound– November 1, 1994 by Myers.
4. Handbook of Immunology. G.P.Talwar, 1983, Vikas publishing house,India.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**1**	**1**	**3**
CO2	**3**	**3**	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**3**	**1**
CO3	**2**	**2**	**2**	**2**	**1**	**3**	**3**	**-**	**2**	**2**	**1**	**2**
CO4	**1**	**1**	**1**	**2**	**3**	**3**	**3**	**1**	**2**	**1**	**-**	**2**

VR-205: CELL BIOLOGY AND IMMUNOLOGY (Compulsory Foundation)

Lecture: 5 hours/week	**Internal test Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: II	**Credits: 4 Credits**

Course Educational Objectives:

1.To understand the structure and contents of prokaryotic and eukaryotic cells, general principles and pathways of cell communication and cell signaling.

2. To describe the concepts and methodologies of plant and animal tissue and organ cultures, cell counting and introduction to stem cell cultures.

3..To learn about the historical perspectives of immunology, innate and adaptive immunity mechanisms,various components of immune system, antigens, antibodies, *in vitro* and *in vivo* antigen and antibody interactions and

4.To understand the mechanism of humoral and cell mediated immune responses, immune effector mechanisms, MHCs, hypersensitivity reactions, autoimmune and immunodeficiency disorders, transplantation and transfusion immunology and concepts and applications of conventional and modern vaccines.

UNIT – I

Cell biology: Introduction to Cell theory; Prokaryotic and eukaryotic cell structure; Nucleus – Ultrastructure of nucleus and nuclear envelope, Nucleolus; chromosomes- Euchromatin and heterochromatin (constitutive and facultative), Polytene and Lampbrush chromosomes; eukaryotic cell cycle, Cell death and proliferation – Apoptosis, mechanism and significance.

Cell Communication – General principles: Cell surface receptors (ion channel-linked, G-protein-linked and enzyme-linked receptors) and intracellular receptors; Types of intracellular signaling – Autocrine, paracrine, contact-dependent, synaptic and endocrine signaling; Intracellular signaling proteins- Types and their role; Second messengers – cAMP pathway and role of calcium; Cell-cell interactions – Adhesion junctions, tight junctions, gap junctions; Cytoskeleton – Structure and functions of microtubules, microfilaments and intermediary filaments; Structure of microvillus.

UNIT – II

Plant tissue culture- Introduction to totipotency of plant cell; Tissue cell culture- Initiation and maintenance of callus and suspension culture, single cell clones, organogenesis, somatic embryogenesis, synthetic seeds, shoot tip culture, rapid clonal propagation and production of virus-free plants; Cryopreservation and germplasm conservation.

Animal tissue culture- Types of tissues – Epithelial, muscle, connective, nerve and blood; Culture media - balanced salt solutions; Composition and metabolic functions of media; Defined media and their applications; Role of serum and supplements, serum-free media; Role of antibiotics in media; Primary culture – Mechanical and enzymatic mode of disaggregation, establishment of primary culture, Subculture - Passage number, split ratio, seeding efficiency, criteria for subculture; Cell lines – Definite and continuous cell lines, characterization, authentication, maintenance and preservation of cell lines.

Cell counting: Hemocytometer, coulter counter; Cell viability and cytotoxicity; Dye exclusion and inclusion tests, clonogenic assay, MTT based assay.

Three-dimensional culture: Organ culture and Histotypic culture; Normal *vs*. transformed cells, growth characteristics of transformed cells.

Stem cells – Introduction and importance of stem cell cultures.

UNIT-III

History: Historical perspectives and milestones in immunology.

Cells and Organs of the Immune system: Hematopoiesis; Cells of the immune system- Lymphoid cells, stem cells, Mononuclear cells, Granulocytes, Mast cells, Dendritic cells; Lymphoid organs- primary and secondary lymphoid organs.

Types of immunity: Innate, adaptive and comparative immunity.

Antigens: types, properties, study of antigenicity, immunogenicity versus antigenicity, factors influencing immunogenicity; epitopes, haptens, mitogens, super antigens.

Antibodies: Types, structures and biological activities of Immunoglobulins, Antigenic determinants; Production of polyclonal antibodies - animals, additives, adjuvants, routes, dose, collection and preservation of antisera; Monoclonal antibodies- principle, production and application of monoclonal antibodies; Introduction to recombinant antibodies and their advantages.
Antigen and Antibody interactions: Affinity, Avidity, Cross reactivity; In vivo serological reactions- Phagocytosis, Opsonization, Neutralization, Protection tests; In vitro serological tests- Precipitation tests, Immuno-electrophoresis (Rocket, counter current), Agglutinations tests- HA & HI, latex agglutination, Complement fixation tests, Labeled antibody based tests- Enzyme linked immunosorbent assays (ELISAs), Western blotting, Radio immunoassay (RIA), Immunoflurescent and Immuno specific microscopy.

UNIT-IV
Humoral immune response: Primary and secondary humoral immune responses; mechanisms of induction and its regulation.
Cell mediated immune response: Antigen processing and presentation, Induction and mechanism, antibody-dependent cell mediates cytotoxicity (ADCC).
Immune effector mechanisms: Cytokines- properties and functions; Toll-like receptors (TLRs); Complement cascade system- complement components, functions, activation pathways.
Major histocompatibility complex (MHC): Organization and Inheritance of MHC, cellular distribution of MHC molecules, MHC restriction, HLA antigens- Class I, II, III and their functions.
Hypersensitivity: Type I, II, III and IV hypersensitivityreactions.
Immunopathology: Immunodeficiency disorders; Phagocyte and complement defects; Autoimmunity and autoimmune diseases.
Transfusion Immunology: Blood cell components, blood group systems in human and in animals, Rh typing, transfusion reactions, diseasesassociated with blood transfusion – Hemolytic anemias, Erythroblastosis fetalis.
Transplantation Immunology: Transplantation antigens, types of transplants, Graft versus host reactions – immunological basis of graft rejection mechanism.
Vaccines: Conventional and modern, production, merits and demerits, applications.

Course Outcomes: At the end of the course the student will be able to

CO1: Discuss the structure and contents of prokaryotic and eukaryotic cells, general principles and pathways of cell communication and cell signaling.

CO2: Understand theconcepts and methodologies of plant and animal tissue and organ cultures, cell counting and introduction to stem cell cultures.

CO3:Learn the history of immunology, types of immunity, cells and organs of immune system and types, structure, and properties of antigens, antibodies, concepts,and methods of *in vivo* and *in vitro* antigen-antibody interactions.

CO4: Describe the induction and mechanism of humoral and cell mediated immune responses, immune effector mechanisms, MHCs, hypersensitivity reactions, immunodeficiency disorders,

basic of transplantation and cancer immunology, concepts, and applications of conventional and modern vaccines.

Suggested books:

Cell Biology

1. The World of the Cell. Becker, W.M., L.J. Kleinsmithand J.H. Hardish. 2007. 6thEdn. Pearson Education, Delhi.
2. Molecular Cell Biology. Lodis, H., A. Berk, C. A. Kaiser, M. P.Scott. 2006. 6thEdn. Ploegh and Paul Matsudaria.
3. Cell and Molecular Biology concepts and experiments. Karp, G. 2005. 4thEdn. John Wiley and Sons, USA.
4. Cell and Molecular Biology. De Robertis, E.D.P and E.M.F. De Robertis. 2001.Lippincott Williams and Wilkins, Bombay.
5. The cell – a molecular approach. Cooper Geoffrey, M. 2000. 2ndEdn. ASM Press, Washington.
6. Molecular biology of the cell. Alberts A et al. 1994. Garland Publishers, New York
7. Cell Biology: organelle structure and function. Sadava, D.E. 1993. Jones and Bartlett Publishers, USA.
8. R. Ian Freshney, "Culture of animal cells – A manual of basic techniques" 4th edition, John Wiley & Sons, Inc, publication, New York. 2000.
9. Daniel R. Marshak, Richard L.Gardner, David Gottllieb "Stem cell Biology" edited by Daniel Cold Spring Harbour Laboratory press, New York. 2001.
10. M.M. Ranga, Animal Biotechnology; Agrobios (India) ,2006. Butterworth "*In vitro* cultivation of Animal Cells"– Heinemann publishers – Open Universities. Nederland, 1994.
11. J. Kruzer , "Recombinant DNA & Biotechnology for Teachers", 2nd Edition, Adrianne Massey, A. Massey & Association.
12. John R.W. Master "Animal Cell culture", University College London, Oxford University press, 2000.
13. ANN A. KIESSLING, SCOTT ANDERSON, Human Embryonic Stem Cells, Jones & Bartlett Publishers, Sudbury, Massachusetts, Boston, Toronto, London, 2003.

14 A.J. Thomson, Gene Targeting & embryonic Stem Cells, Bios Scientific Publishers, Taylor & Francis Group London & New York.

Immunology

1. Immunology. 2000. 4th edition. J. Kuby. W.H. Freeman and Company.
2. Immunology. 1996. 4th edition. I.Roitt, J. Brostoff and David Male. Mosby publications.
3. Fundamental Immunology. 1992. 2nd edition. R.M. Coleman, M.F. Lombard and R.E.Sicard. Wm. C. Brown Publishers.
4. Immunology. 1997. 3rd edition. R.M. Hyde. B.I. Waverly Pvt. Ltd.
5. Immunology. 1995. 4th edition. I.R. Tizard. Saunders College Publishing.
6. Immunology – The Science of self and non-self descrimination. 1982. Jon Klein. John Wiley and Sons.

7. Immunology – An illustrated outline. 1986. David Male. Churchill Living Stone.
8. Viruses that affect immune system. 1991. H.Y. Fan, I.S.Y. Chen, N.Rosenberg and W. Sugden. American Society for Microbiology.
9. Immunobiology: The immune system in health and disease.1994. C.A.Janeway, Jr., P.Travers. Current biology Ltd.
10. Advanced Immunology. D.M. Male *et al.,* The C.V.Mosby Co.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	2	3	3	3	3	3	2	3	3	3
CO2	3	3	2	3	2	3	2	2	3	2	1	-
CO3	2	2	2	2	1	2	3	2	2	2	2	2
CO4	1	1	1	2	1	3	3	1	2	1	-	1

VR-206: HUMAN VALUES AND PROFESSIONAL ETHICS– II
(Elective Foundation)

Lecture: 5 hours/week	**Internal test Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: II	**Credits: 4 Credits**

Course Educational Objectives:

1. To learn the concepts of value education, professional ethics and human values, structure and responsibilities of family system, research ethics, codes of ethics
2. To inculcate knowledge and exposure on safety and risk and to expose student to right attitudinal and behavioral aspects,
3. To enable the students to understand the moral values and ethics followed by medical and health care professionals and businesspeople.

4. To increase the awareness among students about environment and create attitude towards sustainable lifestyle and discuss the social ethics and ethics of media.

UNIT-I

Value Education- Definition - relevance to present day - Concept of Human Values - self introspection - Self-esteem. Family values-Components,structure and responsibilities of family- Neutralization of anger - Adjustability - Threats of family life - Status of women in family and society - Caring for needy and elderly - Time allotment for sharing ideas and concerns.

UNIT-II

Medical ethics- Views of Charaka, Sushruta and Hippocratus on moral responsibility of medical practitioners. Code of ethics for medical and healthcare professionals.Euthanasia, Ethical obligation to animals, Ethical issues in relation to health care professionals and patients. Social justice in health care, human cloning, problems of abortion. Ethical issues in genetic engineering and Ethical issues raised by new biological technology or knowledge.

UNIT-III

Business ethics- Ethical standards of business-Immoral and illegal practices and their solutions. Characterics of ethical problems in management, ethical theories, causes of unethical behavior, ethical abuses and work ethics.

UNIT-IV

Environmental ethics- Ethical theory, man and nature- Ecological crisis, Pest control, Pollution and waste, Climate change, Energy and population, Justice and environmental health.

UNIT-V

Social ethics- Organ trade, Human trafficking, Human rights violation and social disparities, Feminist ethics, Surrogacy/pregnancy. Ethics of media- Impact of Newspapers, Television, Movies and Internet.

Course Outcomes: At the end of the course the student will be able to

CO1: Understand the definition of value education, concept of human and family values, components, structure, and responsibilities of family system and acquire reflective thinking, rational skepticism.

CO2:Describe the moral responsibilities and ethical issues of medical and health care professionals, avoid unethical things, learn ethical issues raised in genetic engineering and new biological technologies.

CO3: Learn to practice ethical standards in business by understanding ethical theories and maintain work ethics to build trust between businessman and consumer and avoid unethical behavior and ethical abuse and develop scientific temper, digital literacy.

CO4: Learn to practice environmental ethics by taking responsibility to protect environment and ecosystem and understand the importance of maintenance of social ethics and ethics of media.

Suggested books:

1. John S Mackenjie: A manual of ethics.
2. “The Ethics of Management” by Larue Tone Hosmer, Richard D. Irwin Inc.
3. “Management Ethics - integrity at work’ by Joseph A. Petrick and John F. Quinn, Response Books:New Delhi.
4. “Ethics in Management” by S.A. Sherlekar, Himalaya Publishing House.

5. Harold H. Titus: Ethics for Today
6. Maitra, S.K: Hindu Ethics
7. William Lilly : Introduction to Ethics
8. Sinha: A Manual of Ethics
9. Manu: Manava Dharma Sastra or the Institute of Manu: Comprising the Indian System of Duties: Religious and Civil (ed.) G.C.Haughton.
10. Susruta Samhita: Tr.KavirajKunjanlal, KunjalalBrishagratha, Chowkamba Sanskrit series, Vol I,II and III, Varnasi, Vol I OO, 16-20, 21-32 and 74-77 only.
11. CarakaSamhita:Tr. Dr.Ram Karan Sarma and Vaidya Bhagavan Dash, Chowkambha Sanskrit Series office, Varanasi I, II, III Vol I PP 183-191.
12. Ethics, Theory and Contemporary Issues., Barbara Mackinnon, Wadsworth/Thomson Learning, 2001.
13. Analyzing Moral Issues, Judith A. Boss, Mayfield Publishing Company, 1999.
14. An Introduction to Applied Ethics (Ed.) John H.Piet and Ayodhya Prasad, Cosmo Publications.
15. Textbook for Intermediate First Year Ethics and Human Values, Board of Intermediate Education-Telugu Akademi, Hyderabad.
16. I.C Sharma Ethical Philosophy of India. Nagin&coJulundhar.

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3				3	2			3	2		1
CO2	3				3	2			3	2		1
CO3	3				3	2			3	2		1
CO4	3				3	2			3			1

SEMESTER-III

VR-301 : PLANT VIROLOGY (Core Theory)

Lecture: 5 hours/week	**Internal test Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: III	**Credits: 4 Credits**

Course Educational Objectives:

1. To define/explain the various concepts related to Plant Virology such as plant virus-host interactions with respect to induction of disease
2. To explain virus movement strategies, plant virus-vector relationships, molecular mechanisms of vector transmission and agroinfection.

3. Tounderstand the plant virus ecological and epidemiological concepts, approaches used for thecharacterization, detection and controlof plant viruses, ecology and epidemiology of plant virus diseases, assessment of disease incidence and yield losses
4. To know about concepts related to conventional and transgenic virus resistance mechanisms andto use this knowledge to conduct biological research as well as to get employability in agricultural research stations and biotechnology industries.

VR-301 : PLANT VIROLOGY (CORE -1)

UNIT-I

Virus-host interactions: Effects of virus infection on host metabolism; molecular mechanisms of plant viral pathogenesis - role of viral genes in disease induction, host proteins induced by virus infection, processes involved in disease induction. Cytological and histological changes in infected plants.Macroscopic external symptoms (local and systemic). Induction of disease- kinds of host response to virus inoculation, factors influencing the course of infection and disease development.
Movement/transport of viruses: Cell to cell and long-distance movement. Distribution of the viruses in the plants.

UNIT-II

Transmission of viruses:non-vector – sap / mechanical, seed and pollen, graft, dodder, contact. Vector- arthropods (aphids, leaf and plant hoppers, whiteflies, beetles, thrips, mealy bugs), mites, fungi, nematodes.Virus-vector relationships, Molecular mechanisms of virus-vector interactions.Effects of viruses on vectors.Agroinfection.

UNIT-III

Characterization and identification of viruses and virus strains: Biological, physical, molecular and immunological approaches.
Detection of Viruses by different approaches: Biological, serological, and molecular assays/tests
Virus ecology and epidemiology of diseases: Epidemiological concepts. Biological and physical factors influencing survival and spread of viruses and diseases. Cropping practices and virus spread. Disease gradients, disease progress curves, mono- and polycyclic diseases. Monitoring of insect vectors.Forecasting of diseases.
Assessment of disease incidence and yield losses: Field surveys for determination of incidence of diseases. Approaches for assessment of yield losses.Impact of viruses on crop yields.

UNIT-IV

Management of virus diseases: Direct and indirect approaches- antiviral agents, crop cultural practices, elimination / avoidance of sources of infection, use of virus-free seeds and planting materials, production of virus-free plants by tissue culture technology, avoidance/control of vectors (chemical and non-chemical approaches). Cross- protection/ immunization.Suppression of disease symptoms by chemicals / botanicals. Control through breeding for disease tolerance / resistance. Production of resistant plants by non-conventional approaches- somatic hybridization, transgenic plants exploiting viral and non-viral genes. Plant quarantine and its role in disease control.

Course Outcomes: At the end of the course the student will be able to

CO1: Understand the induction of plant virus diseases, virus-host interactions, and movement strategies.

CO2: Learn the vector and non-vector modes of plant virus transmission, virus-vector relationships and molecular mechanisms involved in virus vector interactions, effect of viruses on vectors and agro-infection.

CO3: Acquire the knowledge on plant virus spread and survival in nature and biological, serological, and molecular assays/testsused forcharacterization and detection of plant viruses and diseases, concept of ecology and epidemiology of plant viruses and assessment of disease incidence and yield losses.

CO4:Describe the approaches used for the control and management of plant viruses and vectors and strategies used for acquiring plant virus resistance.

Suggested Books:

1. Plant Virology, 4th ed. 2001 by R. Hull (R.E.F. Matthews). Academic Press.
2. Plant viruses as molecular pathogens. J. A. Khan and J. Dijkstra (Eds). CBS Publishers and distributors, New Delhi.
3. Plant Viruses. By M.V. Nayudu. 2008. Tata –McGraw Hill.
4. Applied Plant Virology. 1985. D.G.A. Walkey. Heinemann Publications.
5. Symptoms of Plant Virus Diseases by L. Bos.
6. Diagnosis of Plant Virus Diseases. 1993 by R.E.F. Matthews. CRC Press.
7. Control of Plant virus diseases by Hadidi et al (editors), 1998, American Phytopathological Society, USA.
8. Plant Virus Epidemics- Monitoring, modeling and predicting outbreaks. 1986. G.D. Mc Lean, et. al., Academic Press.
9. Plant Virology - The Principles. 1976 by A. Gibbs and B.D. Harrison, Edward Arnold.
10. Techniques in diagnoses of Plant Viruses (Plant Pathogens -6)-2008 Govind P.Rao, Rodrigo A. Valverde & C.I. Dovas, Stadium Press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**3**	**2**	**3**	**3**	**3**	**2**	**3**	**1**	**3**
CO2	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**2**	**2**	**2**	**-**	**-**
CO3	**2**	**2**	**2**	**1**	**1**	**3**	**3**	**2**	**2**	**1**	**1**	**2**
CO4	**1**	**1**	**1**	**2**	**2**	**3**	**3**	**1**	**2**	**1**	**-**	**1**

VR-302: PLANT VIRUSES AND DISEASES (Core Theory)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**

Semester: III	Credits: 4 Credits

Course Educational Objectives:

1. To understand the distribution, incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management of the virus diseases of cereals and millets, oil seed crops
2. To understand the distribution, incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management of the virus diseases of vegetable, and tuber crops.
3. To acquire knowledge on the distribution, incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management of the virus diseases of food legumes, fruit crops
4. To acquire knowledge on the distribution, incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management of the virus diseases of cash, spice and beverage crops and flowering and foliage ornamentals.

Note: Emphasis shall be on disease distribution, incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management.

UNIT-I

Cereals and millets:

Rice - tungro, dwarf, ragged stunt, grassy stunt, stripe, and yellow mottle. **Wheat**- soil-borne wheat mosaic, streak mosaic, yellow mosaic / spindle streak mosaic and mosaic caused by BYDV. **Barley and Oat** – yellow dwarf, stripe mosaic and yellow mosaic.**Maize andSorghum** – sugarcane mosaic, maize streak , dwarf mosaic, mosaic and stripe viruses caused diseases.

Oil seeds crops :**Groundnut** – bud necrosis, stem necrosis, mottle, stripe, rosette and clump. **Sunflower** – necrosis and mosaic. **Sesamum** – leaf curl. **Rape seed and mustard** – mosaic.**Coconut** – cadang - cadangviriod disease.

UNIT – II

Vegetables: **Tomato** – leaf curl, spotted wilt, mosaic and fern leaf / shoestring. **Chilli** – leaf curl, vein banding and mosaic caused by TMV, CMV and TEV. **Brinjal** – mosaic caused by CMV / TMV/ PVY. **Okra** – yellow vein mosaic and leaf curl. **Onion andgarlic** – yellow dwarf mosaic, latent and iris yellow spot. **Cucurbits** – CMV.squash mosaic and leaf curl, watermelon mosaic and bud necrosis, and cucumber green mottle mosaic. **Radish** – mosaic. **Carrot** – red leaf, mottley dwarf and thin leaf. **Cabbage andCauliflower**- turnip mosaic, cauliflower mosaic and turnip yellow mosaic.

Tuber crops:Potato- leaf roll, rugose mosaic, mild mosaic / latent caused PVX, PVM and PVS and spindle tuber viriod diseases.**Sweet potato** – mild and feathery mottle.**Cassava** – common, African

and Indian mosaic diseases. **Colocasia and Cocoyam** – Feathery mottle, Babone and Alomae diseases.**Greater yam** – mosaic.

UNIT-III

Food legumes: French bean- Common mosaic, yellow mosaic, golden mosaic, leaf roll and CMV infection. **Soybean** – mosaic, dwarf and TRSV infections. **Pea** - seed-borne mosaic, enation mosaic, BYMV. **Cowpea** – yellow and severe mosaic, golden yellow mosaic, SBMV and CMV. **Chickpea** – stunt, chlorotic dwarf, CMV and AMV infections. **Pigeonpea**– sterility mosaic.**Lentil** – diseases caused by Bean leaf roll and yellow mosaic viruses. **Black gram / Green gram** – yellow mosaic and leaf crinkle. **Horse gram** - yellow mosaic.

Fruit crops : Banana / Plantain - bunchy top, streak, infectious chlorosis and bract mosaic. **Citrus** - tristera, yellow mosaic, psorosis and exocortis. **Papaya**- ring spot, leaf curl and mosaic.**Grapevine** - fern leaf and leaf roll.**Apple** - mosaic.**Pineapple** - wilt.

UNIT-IV

Cash crops: Sugarcane- mosaic, Fiji disease, bacilliform virus. **Sugarbeet** -curly top yellows, western yellows, beet mosaic, BNYV. **Cotton** - leaf curl diseases, **Kenaf**- yellow vein mosaic. **Tobacco** - mosaic and leaf curl.

Spice and beverage crops: Smallcardamom – mosaic. **Large cardamom** - foorkey and chirke diseases.**Black Pepper** - stunt and yellow mottle. **Zinger** – chlorotic fleck. **Vanilla-**mosaic.**Cocoa** - swollen shoot.

Flowering and foliage ornamentals:Tulips– Flower breaking. **Rose –** mosaic.**Gladiolus–** BYMV. **Orchids –** cymbidium mosaic and odontoglassum ring spot viruses. **Carnations** - mottle, ring spot and etched ringspot. **Chrysanthimum –**aspermy, ring mottle and stunt viriod. **Aroids –** DSMV and Konjac mosaic viruses.

Course Outcomes: At the end of the course the student will be able to

CO1: Describe the incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management of the major virus diseases of cereals, millets, and oil seed crops.

CO2: Learn the incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management of the major virus diseases of vegetable and tuber crops.

CO3: Acquire the knowledge of incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management of the major virus diseases of food legumes and fruit crops.

CO4:Understand the incidence and impact, symptoms, causal virus characteristics, diagnosis, disease cycle and management of the major virus diseases of cash, spice, beverage, flowering, and foliage ornamental crops

Suggested Books:

1. Characterization, Diagnosis & Management of Plant Viruses: Industrial crops (vol.I) (Plant pathogens series-I) 2008-Govind P.Rao, S.M. Paul Khurana & S L.Lenardan-Studium press LLC, U.S.A
2. Characterization, Diagnosis & Management of Plant Viruses: Horticultural crops (vol.2) (Plant pathogens series-2) 2008-Govind P.Rao, Arben Myrta and Kal-Shu Ling-Studium press LLC, U.S.A
3. Characterization, Diagnosis & Management of Plant Viruses: Vegetables & Pulse crops(vol.3) (Plant pathogens series-3) 2008-Govind P.Rao, P.Lavakumar and R.J. Holguin-Pena-Studium press LLC, U.S.A
4. Characterization, Diagnosis & Management of Plant Viruses: Grain crops & Ornamentals(vol.4) (Plant pathogens series-4) 2008-Govind P.Rao, Claude Bragard and B S.M.Lebas-Studium press LLC, U.S.A
5. Plant pathology, Fifth edition-2008- GeorgenAgrios-Elsevier.
6. Techniques in diagnoses of Plant Viruses (Plant Pathogens -6)-2008 Govind P.Rao, Rodrigo A. Valverde & C.I. Dovas, Stadium Press.
7. Viruses and Virus-Like Diseases of Major crops in Developing Countries-2003. G Loebenstein& G. Thottappilly. Kluwer Academic Pub.
8. Viruses and Virus diseases of Poaceae(Gramineae)-2004.H.Lapierre & P.A. Siganoret. INRA editions-France.
9. Viruses of Plants. 1996. By A.A. Brunt et al., CAB International.
10. Virology in the Tropics. 1994. N. Rishi, et al., (editors). Malhotra Publishing House.
11. Control of Plant Virus diseases by Hadidi et al., 1998. American Phytopathological Society, USA.
12. American Phytopathological Society- Monographs on disease of different crops.
13. CMI/AAB Descriptions of Plant Viruses.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**1**	**3**	**2**
CO2	**3**	**3**	**3**	**3**	**2**	**3**	**-**	**2**	**2**	**-**	**1**	**2**
CO3	**2**	**2**	**2**	**2**	**1**	**3**	**3**	**2**	**2**	**2**	**1**	**1**
CO4	**1**	**1**	**1**	**-**	**2**	**3**	**3**	**1**	**2**	**1**	**-**	**1**

VR-303: CORE PRACTICAL: PLANT VIROLOGY AND PLANT VIRUS DISEASES

Lecture: 9 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Textbooks, E-learning	

resources, study materials	
Semester: III	**Credits: 4 Credits**

Course Educational Objectives:

1. To acquire practical knowledge on identification of symptoms of major viruses on economically important local crop plants, weeds and to determine effect of viruses on plant metabolism and health.

2. To develop practical skills in identification of plant viruses using serological and molecular tests, to learn modes of plant virus transmission, and to explore local field survey for estimation of plant virus disease incidence and progress.

List of Practicals:

1. Study of symptoms of local virus diseased plants and through slides/photographs
2. Determination of virus effect on chloroplast number.
3. Determination of virus effect on cell size.
4. Observation of inclusions by light microscopy
5. Determination of concentration of carbohydrates, proteins and lipids in seeds of viru infected plants.
6. Identification of unknown virus by ELISA.
7. Transmission of plant viruses by leaf hoppers / whiteflies / cuscuta.
8. Determination of virus effect on yield components
9. Isolation of single lesion virus isolates
10. Local field surveys and research stations.
11. Diagnosis of virus diseases (theoretical exercises).
12. Collection and identification of local insect vectors.
13. Determination of disease progress curves.
14. Study of seed transmission of viruses
15. Demonstration of transmission of viruses through vegetative propagules
16. Production of virus-free plants by tissue culture technology

Course Outcomes: At the end of the course the student will be able to

CO1: Identify major virus diseases of local economically important crop plants and weeds through theoryexercises, local field surveys, agricultural research station visits.

CO2:Determine and compare the effect of virus on cell size, chloroplast number, total carbohydrates, proteins, and lipids with healthy counterparts.

CO3:Detect unknown viruses through ELISA and PCR (theory exercise and practical) and demonstrate plant virus transmission by seed and vegetative propagules and generation of virus free plants through apical meristem tip culture.

CO4: Identify local plant virus vectors, determine virus disease incidence, and progress curves through local field visits.

Suggested Books / Manuals:

1. Serological Methods for detection and identification of viral and bacterial plant pathogens: A Laboratory Manual. 1990. R. Hampton et al., APS Press.
2. Diagnosis of Plant Virus Diseases, 1993. R.E.F. Matthews (ed.) CRC Press.
3. Methods in Plant Virology, 1984. S.A. Hill. Blackwell Publications.
4. Methods in Virology, K. Marmorosch and H. Koprowski. Vol. I and II. Academic Press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	2	1	1	2
CO2	3	3	3	-	2	3	2	2	2	2	-	2
CO3	2	2	2	2	2	3	3	2	2	2	1	2
CO4	1	1	1	2	1	3	3	1	2	1	-	1

VR-304: PRACTICAL: MOLECULAR VIROLOGY (OR) BIOSTATISTICS AND BIOINFORMATICS (CORE-4)

a) MOLECULAR VIROLOGY

Lecture: 6 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Textbooks, E-learning resources, study materials	
Semester: III	**Credits: 4 Credits**

Course Educational Objectives:

1. To acquire skills and technologies related to purification of viruses such as culture of viruses on propagation harvesting virus infected leaves, homogenization, clarification, concentration, further purification, final pelleting and to check the quality and quantity of the viruses.

2. To isolate and analyze virus nucleic acids and proteins using agarose gel and polyacrylamide gel electrophoresis, respectively and to determine the effect of physical and chemical agents on inactivation of viruses.

List of Practicals:

1	Purification of viruses by different chemical and physical methods
2	Isolation of viral proteins and nucleic acids
3	Analysis of viral proteins and nucleic acids by spectroscopy and gel electrophore
4	Isolation and analysis of dsRNA from ssRNA infected tissues
5	Study of inactivation of viruses by various physical and chemical agents

Course Outcomes: At the end of the course the student will be able to

CO1: Acquire the skills to use the techniques involving purification of viruses such as maintenance of virus cultures on propagation hosts, clarification using organic solvents and low speed centrifugation, precipitation using sodium chloride or ammonium sulphate or polyethylene glycol or differential centrifugation, preparation of step and linear density gradients, further purification of viruses using sucrose density gradient centrifugation and final pelleting by ultrafiltration or ultracentrifugation and to check the quality and quantity of viruses using spectroscopy or transmission electron microscopy.

CO2: Isolate virus coat proteins and determine its quantity and molecular weight through spectroscopy and SDS-PAGE, respectively.

CO3: Isolate virus nucleic acids (dsRNA, RNA and DNA), estimate their quantity by spectroscopy,determinetheir size and molecular weight through agarose gel electrophoresis.

CO4: Determine the stability of virus by studying effect of physical and chemical agents on virus inactivation.

Suggested books / manuals:

1. Virology - A Laboratory Manual, 1992. By Burleson, et al., Academic Press.
2. Virology Methods Manual, 1996. B.W.J. Mahy and H.O. Kangro. Academic Press
3. Molecular Virology: A Practical Approach. 1993. Davison and R.M. Elliot. Oxford University Press.
4. Virology Lab Fax. 1993. D.R. Harper. Bioscientific Publication. Academic Press

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	2	2	3	-
CO2	3	3	3	3	2	2	2	2	-	1	1	2
CO3	2	2	2	2	1	3	3	2	2	3	1	2
CO4	1	1	1	1	3	2	3	1	2	1	-	1

(OR)

b) BIOSTATISTICS AND BIOINFORMATICS

Lecture: 6 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Textbooks, E-learning resources, study materials.	
Semester: III	**Credits: 4 Credits**

Course Educational Objectives:

1. To learn using MS Office, creating tables in MS-Word, creating database, spreadsheet and statistical graphs, sample statistics with Excel.

2. To acquire knowledge to use internet, worldwide web and searching for databases, searching for research material in PubMed, use of bioinformatics tools for the analysis of DNA and to analyze the virus genome using Bio Edit.

List of Practicals:

1 Cut, copy, paste operations in MS Office

2 Creating & editing tables in MS-Word

3 Creating database & Statistical graphs in EXCEL
Histogram, pie, line diagram, scatter diagram, error bars

4 Simple Statistics with Excel

5 Creating and use of spread sheet to biological applications

6 Use of internet, worldwide web, searching for data bases

7 Locating research material on Medline

8 Learning to use NCBI and EMBL and phylogenetic trees.

9 Analysis of Viral genome sequences using programs like Bio Edit.

Course Outcomes: At the end of the course the student will be able to

CO1: Learn how to use MS office and create, edit tables in MS word.

CO2: Develop knowledge to do simple statistics with Excel, to create statistical graphs and spread sheets in Excel for biological applications.

CO3:Use internet, web tools, databases, and search engines for designing, planning, and executing biological research experiments or investigations.

CO4:Analyze viral genome sequences using programs like Bio Edit and learn to use NCBI, EMBL for nucleic acid/protein analysis and phylogenetic tree construction.

Suggested books / manuals:

1. Elements of Computer Science, 1998. S.K. Sarkar, A.K. Gupta. S. Chand & Company (Chapters- 1,2,9,12,14).
2. Microsoft Office. 1997. Stultz. Office 2000 -The Basics and Beyond, 2000. A Lan Neibauer. Tata Mc Graw-Hill Publishing Comp. Part I, II, III, IV, V.
3. Bioinformatics: Methods and Protocols, Edited by StephemMisener and Stephen A. Krawetz. 2000. Methods in Molecular Biology Series. Humana Press.
4. Bioinformatics: A Practical guide to the analysis of genes and proteins. 1998. Edited by A.D. Baxevanis and B.F.
5. Francis Ouellette. Wiley -Interscience. Computational Methods in Molecular Biology by S.L. Saizberg.
6. Computer Applications in Biotechnology. 1998. by T. Yosida. Introduction to Bioinformatics by Atwood.
7. Bioinformatics - From Nucleic Acids and Proteins to Cell Metabolism. 1995, by Schomburg and Label VCH Publ.
8. Bioinformatics: Sequence and Genome Analysis. By D.W. Mount. CSHL Press.
9. Bioinformatics: Methods and Protocols, Ed by S.Misener and S.A. Krawetz. Humana Press, 2000.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**3**	**1**	**2**	**3**	**3**	**2**	**2**	**1**	**2**
CO2	**3**	**1**	**3**	**1**	**2**	**3**	**2**	**2**	**2**	**3**	**3**	**2**
CO3	**2**	**2**	**2**	**2**	**1**	**-**	**3**	**2**	**2**	**-**	**1**	**3**
CO4	**1**	**1**	**1**	**1**	**-**	**3**	**3**	**1**	**2**	**1**	**-**	**1**

VR-305 : MOLECULAR VIROLOGY (GENERIC ELECTIVE)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignments**

Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: III	**Credits: 4 Credits**

Course Educational Objectives:

1. To understand molecular architecture of viruses and molecular mode of inactivating agents on viruses
2. To learn about types of viral genomes and steps involved in virus replication and replication strategies of DNA viruses.
3. To acquire knowledge about expression and replication of RNA viruses
4. To discuss about the regulation of viral genome expression and molecular mechanisms in inducing tumors by tumor viruses and replication of subviral agents.

UNIT-I

Molecular architecture of viruses: Principles of virus structure- Icosahedral and helical tubes (TMV), cubic symmetry, in vitro reconstitution experiments, structured-based categories of viral designs and their characteristics- simple icosahedral symmetric capsids with Jelly-Roll Beta barrel sub-units (Polio, TBSV, SBMV, SeMV), ds DNA (Pox virus, Baculovirus, HSV, Adeno) dsRNA viruses (Reovirus), enveloped positive-stranded RNA viruses, enveloped viruses with trimeric, alpha helical, coiled-coil fusion proteins. Viruses with head-tail morphology- (T4). Occurrence of different morphologies, principles of disassembly- particles are metastable.

Molecular mode of inactivating agents on viruses: physical agents – ionizing radiation; non-ionizing radiation, temperature (heat); ultrasonic vibration. Chemical agents – inorganic; organic solvents; ions; chelating agents; hydroxylamine; dyes.

UNIT-II

Viral genomes: Structure and complexity of viral genomes, diversity among viral genomes- DNA genomes- linear and circular double and single stranded. RNA genomes- Positive and Negative, linear, circular, double and single stranded, mono, bi, tri and multipartite genomes.

Replication of viruses: Investigation of virus replication, an overview of virus replication cycles , replication strategies, host cell functions required in virus replication, sites of replication and assembly, importance of mutants in assembly studies.

Replication strategies of DNA viruses: Baltimore strategies on viral genome expression, Replication of DNA viruses, transcription of viral DNA, preparing the cell for viral DNA replication, universal mechanism of viral DNA replication, strategies to ensure complete replication, genome resolution, packaging, replication of circular dsDNA - Papoviruses, replication of linear dsDNA that conform circles- Herpes, Lambda; replication of linear dsDNA genomes- Adeno, Pox , replication of ss circular DNA- phi x 174, replication of linear ssDNA - parvo, dependence versus autonomy among DNA viruses. Gene expression and its regulation in DNA viruses- Polyoma, Adeno, Pox, Parvo, Retro, Hepadna, DNA phages, papilloma and Herpes viruses.

UNIT-III

Expression and replication of RNA Viruses: Structure and organization of viral RNA genomes, regulatory elements for RNA virus genome synthesis, synthesis of the RNA genomes. Viruses with positive sense ssRNAs - MS2/ Q β, Picorna- Toga-, Tobamo-, Poty-, Nepo- and Bromo- viruses. Negative and Ambisense ss RNA viruses- Ortho-, Paramyxo, Bunya and Rhabdo- viruses. dsRNA viruses- Reo- and Birna- virues. ssRNA viruses with DNA intermediate - RSV and HIV. dsDNA viruses with RNA intermidate- CaMV, Hepatitis B.

UNIT-IV

Regulation of viral genome expression: MS2, T4, Lambda phage, Corona virus, HIV, Adenovirus and Herpesvirus. Functions of virus encoded products. Assembly of viruses- self-assembly from mature virion components, assembly of virus with helical structure (TMV), isometric structure (Adeno, Picorna) and with complex structure (T4).Assembly of enveloped viruses (Herpes, Filo, Retroviruses).Maturation of virus particles.

Tumor Virology: Terminology. Viruses associated with tumors. Molecular mechanisms of tissue transformation and tumorogenesis by viruses.

Replication of sub-viral agents: Viroids, Hepatitis D, Sat-viruses, Sat-RNAs, DI particles, Prions.

Course Outcomes: At the end of the course the student will be able

CO1: Acquire knowledge about principles of virus architecture and effect of physical and chemical agents on viruses.

CO2: Learn about structure and diversity of viral genomes, general concepts of replication of viruses and expression and replication strategies of DNA viruses.

CO3: Learn about structure and organization of viral RNA genomesand expression and replication of different RNA viruses.

CO4: Describe the regulation of viral genome expression and concepts/molecular mechanisms of celltransformation by tumor viruses and replication of subviral agents.

Suggested Books:

1. Principles of Virology- Molecular biology, pathogenesis and control. 2004. S.J.Flint, L.W.Enquist, R.M.Krug, V.R.Racaniello and A.M.Skalka.ASM press.
2. Principles of Molecular Virology. 1997.Second edition. A.J. Cann. Acad. Press.
3. Medical Virology. 2001. 5th edition. D.O. White, F.J. Fenner. Academic Press.
4. Introduction to Modern Virology. 2001. 5th edition. Dimmock et al. Blackwell Sci.
5. Matthews' Plant Virology. 2001. 4th edition. R. Hull. Academic Press.
6. Virology. 1994. 3rd edition. Fraenkel Conrat, P.C. Kimbal and J.A. Levy. Printice Hall.
7. Basic Virology. 1999.E.K. Wagner and M.J.Hewlett. Blackwell Science, INC.,

8. Fundemental Virology.2001.4th Edition. Editors-in-Chief David M.Knipe, Peter.M.Howley. Lippincott.
9. Fields Virology. 1996. 3rd Edition. B.N. Fields, D.M. Knipe, P.M. Howley.
10. Encyclopedia of Virology. 1994. R.G. Webster and A. Granoff (9ed.). Vol. I,II and III.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	2	1	3	3
CO2	3	3	3	2	1	3	2	2	-	2	1	2
CO3	2	2	2	1	1	3	3	2	-	2	2	-
CO4	1	1	1	2	2	3	3	1	2	1	-	1

(OR)

VR 305: BIOSTATISTICS AND BIOINFORMATICS (GENERIC ELECTIVE)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: III	**Credits: 4 Credits**

Course Educational Objectives:

1. To understand basic concepts of statistics, construction of histogram, normal distribution, mean, median and standard deviation, comparison of means and variances, examples of proportion and count data
2. To learn about analysis of variance, correlation and regression and statistical parameters for biological assays.
3. To learn basics of personal computer and its components, windows operating system, Microsoft office-2000, basics of internet browsing of biological data, computer networking and information networks.
4. To learn basics of databases and tools, sequence analysis, phylogenetic analysis using bioinformatics tools and predictive methods using nucleotide and protein databases.

UNIT-I

Introduction: Definition of statistics: population and universe, the sample and population, statistical inference; parameter and statistics. Construction of a histogram; Interpretation of histogram, the normal distribution, the mean, mode, median and standard deviation.
Uncertainties in estimation of mean, comparison of means and variances- t, F, and Z tests.

Proportion data: examples of proportion data; (MPN, sterility testing of medicines, animal toxicity, therapeutic trial of drugs and vaccines, animal toxicity, infection, and immunization studies) statistical treatment to proportion data. Chi-square test, goodness of fit.
Count data: examples of count data (bacterial cell count, radioactivity count, colony, and plaque counts) statistical treatment to count data: Poisson distribution, standard error, confidence limits of counts.

UNIT-II
Analysis of variance: Analysis of variance: Introduction, procedure and tests for one-way and two-way classified data. Multiple comparisons.Analysis of CRD, RBD and LSD.Factorial experiments-main effects and interaction in a 2^2 design.
Correlation and regression, formulae and application.Fitting the best straight line through a series of points.Fitting of different curves. Standard curves and interpolation of unknown Y-values. Multiple linear regression.
Statistical basis of biological assays: Response-Dose metameter. Delusion Assays, Direct and indirect assays. Quantal Responses, Probit, logit, LD_{50}, ED_{50}, PD_{50} - Standard line interpolation assay, parallel assay (4-point, 6-point assays), slope ratio assay.

UNIT-III
Basics of personal computer and its components.Concept of Programming Languages.Hardware and Software.The idea of operating systems.
Windows Operating system - Simple commands do create directories and handle files. Windows based software for creating biological databases- MS access
Microsoft Office-2000: Introduction and facilities available.Shortcut Bar; customizing toolbars; using common office techniques- starting an office application. Microsoft Word, Microsoft Excel, Microsoft PowerPoint.
Introduction to Internet and Biologist: Internet basics, getting onto the internet, e-mail, file transfer protocols, gopher, the world-wide web, browsing and downloading from sites.
Networking of Computers and overview of International and Indian networks. Virtual Library-I: Searching MEDLINE; PubMed. Virtual Library II: Science Citation Index and current awareness services; Virtual Library III: Electronic Journal; International and Indian Networks- NICNET, INFLIBNET, AGRIS.
Information Networks: WWW, HTTP, HTML, URLs, EMB net, NCBI net and Virtual tourism.

UNIT-IV
Databases and Tools: Primary information resources- Protein and genomic information resources-Biological databases; primary, secondary and composite protein sequence databases, structure classification databases, DNA sequence databases, specialized genomic resources; DDBJ, Gen Bank and EMBL public DNA sequence databases; SWISSPROT Database, information retrieval from biological databases; the NCBI data model. Submitting DNA sequences to the Database and updating.
Sequence analysis: Wisconsin GCG, DNASIS, DNASTAR, CLONE MANAGER packages for nucleotide sequence analysis; sequence alignment and database searching; practical aspects of multiple sequence alignment.
Phylogenetic analysis: Phylogenetic models; multiple alignment procedures (CLUSTAL, ALIGN, PHYLIP); tree building methods and trees evaluation; rooting trees, phylogenetic software.

Predictive methods using nucleotide and protein sequences: Detecting regulatory elements in the DNA; physical properties of proteins based on sequences, different protein structural motifs, RNA binding domains and folding classes; Transcription factors and their DNA binding. Protein structure predictions.

Course Outcomes: At the end of the course the student will be able to

CO1: Understand basic concepts of statistics, construction of histogram, normal distribution, mean, median and standard deviation, comparison of means and variances, examples of proportion and count data.

CO2:Learnthe concepts of analysis of variance, correlation and regression and applications of statistical parameters for biological assays.

CO3:Learnbasics of personal computer and its components, windows operating system, Microsoft office-2000, basics of internet browsing of biological data, computer networking and information networks.

CO4:Acquire knowledge about databases and tools, sequence analysis, phylogenetic analysis using bioinformatics tools and predictive methods using nucleotide and protein databases.

Suggested Books:

1. Biostatistics by Daniel.
2. Campbell R.C. (1974) Statistics for Biologists, Cambridge University Press, Cambridge.
3. Statistics made simple-Do it yourself on PC. 2001. By K.V.S. Sarma. Printice Hall of India Publ.
4. An introduction to Biostatistics. 1997. Third Edition. P.S.S. Sundar Rao and J. Richard, Prentice-Hall of India Pvt. Ltd., New Delhi.
5. Fundamentals of Biostatistics. 1994. First Edition. Irfan A. Khan and Atiya Khanum, Ukaaz Publications.
6. Biostatistics. 1996. First Edition. P.N. Arora and P.K. Malhan, Himalaya Publishing House.
7. Statistics for Biologists. 1980. D.J. Finney.
8. Statistics and Experimental design: An Introduction for Biologists and Biochemists. 1994. 3rd edition. G.M. Clarke. Edward Arnald Publications.
9. Statistical methods. 1967. 6th edition. Snedecor and Cochran, Oxford Press. 1967.
10. Elements of Computer Science, 1998. S.K. Sarkar, A.K. Gupta. S. Chand & Company (Chapters-1,2,9,12,14).
11. Microsoft Office. 1997. Stultz. Office 2000 -The Basics and Beyond, 2000. A Lan Neibauer. Tata Mc Graw-Hill Publishing Comp. Part I, II, III, IV, V.
12. Windows-98, 2000, VickramCrishra. Tata Mc Graw-Hill Publishing.
13. The Internet: Complete Reference, Harley Hahn. 1996. Second Edition. Tata Mc Graw-Hill Publication.
14. Introduction to Bioinformatics, 2001 by T.A. Attwood & D.J. Parry-Smith, Pearson Education Asia Publ.
15. Bioinformatics: Methods and Protocols, Edited by StephemMisener and Stephen A. Krawetz. 2000. Methods in Molecular Biology Series. Humana Press.

16. Bioinformatics: A Practical guide to the analysis of genes and proteins. 1998. Edited by A.D. Baxevanis and B.F.
17. Francis Ouellette. Wiley -Interscience. Computational Methods in Molecular Biology by S.L. Saizberg.
18. Computer Applications in Biotechnology. 1998. by T. Yosida. Introduction to Bioinformatics by Atwood.
19. Bioinformatics - From Nucleic Acids and Proteins to Cell Metabolism. 1995, by Schomburg and Label VCH Publ.
20. Bioinformatics: Sequence and Genome Analysis. By D.W. Mount. CSHL Press.
21. Bioinformatics: Methods and Protocols, Ed by S.Misener and S.A. Krawetz. Humana Press, 2000.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	3	3	2	3
CO2	3	3	3	3	2	2	2	2	2	1	3	2
CO3	2	2	2	2	1	3	3	-	3	2	-	-
CO4	1	1	1	2	3	3	3	1	2	1	-	1

VR-306: BIOLOGY OF VIRUSES OF MICRO ORGANISMS (OPEN ELECTIVE)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: III	**Credits: 4 Credits**

Course Educational Objectives:

1.Todescribe viruses of prokaryotes, biology of bacteriophages of enterobacteria

2. To learn about biology of representative widely occurring phages, cyanobacteria, mycoplasmas, and archaea.

3. To learn aboutbiology and properties of important viruses of eukaryotic microorganisms such as fungi, yeast

4.To learn about biology and properties of important viruses of higher fungi, algae, and protozoa.

UNIT-I

Viruses of prokaryotes: Bacteriophages- Discovery, isolation, propagation, and assay of bacteriophages. Purification and characterization.Nomenclature and classification of bacteriophages.Importance / applications of bacteriophages in biology, agriculture, industry, and medicine.
Biology of bacteriophages of enterobacteria (dsDNA phages – T_2, T_4, T_7, lambda, Mu, P_1, P_{22}, PRD. ssDNA phages – øx-174, M_{13}, f_1, fd. ssRNA phages-MS_2, f_2, Qβ, R_{17}).

UNIT-II
Biology of representative widely occurring phages: Phages of *Bacillus, Lactobacillus, Lactococcus, Listeria, Staphylococcus, Streptococcus, Vibrio, Clostridium, Mycobacterium, Coryniform, Actinomycetes, Pseudomonas*, *Xanthomonas* and *Rhizobium*.
Phages of cyanobacteria: *Podoviridae*– A-4(L), Ac-1, LPP-1, SM-1, *Myoviridae*-AS-1, N1, S-6(L), *Siphoviridae*-S-2L, S-4L
Phages of mycoplasmas: Properties of *Plasmavirus, Plectovirus, Spiromicrovirus*genera.
Phages of *Archaea:* ψ M1-like viruses, *Lipothrixvirus, Rudivurs, Fusellovirus, Sulfolobus*and SNDV-like viruses.

UNIT-III
Viruses of eukaryotic microorganisms: Fungal viruses: Discovery, isolation, propagation, titration, purification and caractérisation of. Nomenclature and classification of viruses.Importance / applications of fungal viruses in biology.
Viruses of yeasts: *Sacchromyces cerevisiae -Totiviridae:* ScV-L-A, ScV-L-B6,*Narnaviridae:* ScNV-20S, ScNV-23S.*Pseudoviriae:* SceTY1V, SceTY2V, SceTY3V, *Metaviridae:* SceTY3V, *Schizosaccharomyces pombe* viruses.

UNIT-IV
Viruses of higher fungi: *Penicillium* spp.-*P. chrysogenum*virus (PcV), *P. stolanigerum*(PsV).
Aspergillus spp.-*A. foetidus*(AfV), *A. niger virus* S (AnV-S), *A. ochraceous* virus (AoV).
Viruses of *Gaeumnnomycesgraminis, Rhizoctonia solani, Ustilago, Agaricus*and *Helminthosporium.*
Algal viruses: Isolation, characterization, and properties of *Phycodnaviruses*and their importance.
Biology of protozoan viruses: dsRNA: Giardia virus, Leishmania virus, Amoeba virus.

Course Outcomes: At the end of the course the student will be able to

CO1: Describe the discovery, isolation, propagation, and assay of viruses of bacteria and biology of bacteriophages of enterobacteria.

CO2: Understand the biology and properties of representative widely occurring phages, phages of cyanobacteria, mycoplasmas, mycoplasmas, archaea.

CO3: Learn about biology and properties of major viruses of fungi and yeast.

CO4: Acquire knowledge about biology and properties of major viruses of higher fungi, algae, and protozoa.

Suggested books:

1. Bacteriophages. H.W. Auckerman. 2004. In: The desk top encyclopedia of microbiology. Schaechter.M. (ed). Elsevier, Academic Press.
2. Phycodnaviridae-Large DNA algal viruses. 2002. By Van Etten et al.. Archives of Virology. 147: 1479-1516.
3. Virus Taxonomy: Classification and Nomenclature. (Seventh report of ICTV).2000. By M.H.V. Van Regenmortel*et al.,* (Eds) Academic Press.
4. Encyclopedia of Virology. 1999. 2nd Edition. Vol. 1, 2, 3. Webster, R.G. and Granoff, A. (Eds). Academic Press.
5. Wilson, D.R. and Finley, B.B. 1998. Phage Display: Applications, innovations and issues in phage and host biology. Canadian J. Microbiol. 44: 313-329.
6. Viruses of Protozoa. 1991. By T.C. White and C.C. Wang. Ann. Rev. Microb. 45: 251-263.
7. The Bacteriophages. 1988. Vol.1, 2. By Calender, R. (Ed).
8. Viruses of Fungi and Simple Eukaryotes. 1988. By. Y. Koltin and M. Leibowitz. Mareed Dekker.
9. Viruses of prokaryotes. Vol. 1 and 2. 1987. Auckermann. H.W. and Du Bow, M.S. CRC press.
10. Fungal Virology. 1986. By Buck, K.W. (Ed). CRC Press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	1	3	3	3	3	1	1	3
CO2	3	3	3	2	2	3	2	2	1	2	-	2
CO3	2	2	2	2	1	3	2	2	-	-	1	1
CO4	1	1	1	2	2	3	3	1	2	1	-	1

(OR)

VR-306: BIOLOGY OF VIRUS VECTORS AND THEIR MANAGEMENT (OPEN ELECTIVE)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: III	**Credits: 4 Credits**

Course Educational Objectives:

1. To understand the basics of general entomology, collection, preservation, maintenance and transportation of virus vectors and vector-borne viruses of animals and humans
2. To learn about the biology and ecology of mosquitoes, blood sucking mites and prevention and control methods of animal and human virus vectors in urban and rural settings.
3. To describe the methods of collection, culturing and identification of plant virus vectors, virus vector transmission mechanisms,

4. To learn about the soil-borne vectors, epidemiology of vector-borne viruses, management of plant virus vectors and concepts of vector resistant crops.

UNIT-I

Introduction to general entomology: Insect morphology and classification. Arthropod and other insects of virus vector importance, their structures and functions. Methods for arthropod vector collection, preservation / maintenance, and transportation.

Identification of major groups of arthropod vectors - Molecular approaches for identification of vector species.

Arboviruses of animals and humans: Flaviviruses, Togaviruses, Bunyaviruses, Reoviruses, Rhabdoviruses.

UNIT-II

Biology and ecology of mosquitoes: Biology and life history of *Aedes, Culex and Anopheles* – their behavior and ecology with special reference to dengue, chikungunya, Japanese encephalitis, equine encephalitis and west nile.

Biology and ecology of other blood sucking insects (Ticks): Biology, morphology and disease relationships of sandflies (Crimean-Congo hemorrhagic fever, sandfly fever and chandipura).

Biology and morphology of fleas, lice and culicoides (blue tongue virus, African horse sickness virus).

Biology, ecology and life history of ticks with special reference to Kyasanur forest disease.

Prevention and management of animal and human virus vectors in urban and rural settings: Physical, chemical, biological, and other approaches.

UNIT-III

Plant virus vectors

Arthropods and mites: Collection and identification of aphids, leaf and plant hoppers, whiteflies, thrips, beetles, mealybugs, and mites. Monitoring of these different groups of vectors.Culturing of insect vectors for transmission studies.Virus-vector transmission mechanisms – non-circulative (nonpersistent, semipersistent, bimodal), circulative (propagative and nonpropagative).Experimental transmission of plant viruses by insect and mite vectors.Effects of viruses on vectors.

UNIT-IV

Fungal and nematode vectors: Collection and identification of these vectors. Mechanisms of transmission of viruses by fungi (Olpidium, Polymyxa and Spongospora) and nematodes (Longidorids and trichodorids).Experimental transmission of plant viruses by fungal and nematode vectors.

Epidemiology of vector-borne viruses: Impact of climatic factors (temperature, rainfall, humidity, wind speed and direction), soil factors and cropping practices.

Management of plant virus vectors: Physical, chemical, biological, and other approaches.

Vector resistant crops: Natural and transgenic resistance.

Course Outcomes: At the end of the course the student will be able to

CO1: Understand the insect morphology and classification, types, structure of virus vectors, culturing, collection, preservation, and transportation of virus vectors and molecular approaches for identification of major arthropod virus vectors.

CO2: Describe thebiology, ecology, and life cycle of mosquitoes with reference to major mosquito-borne virus diseases and physical, chemical, biological, and other approaches for prevention and management of animal and human virus vectors in urban and rural settings.

CO3:List and discuss the important vectors transmitting plant viruses, their culturing, virus vector relationships, molecular mechanisms of vector transmission, effects of viruses on vectors.

CO4:Learn about biology, ecology and life cycle of nematodes and fungal vectors and demonstration of experimental nematode and fungal transmission of plant viruses, impact of climatic factors, soil vectors and cropping practices on epidemiology of vector-borne viruses, physical, chemical, biological, and other approaches for prevention and management of plant virus vectors and natural and transgenic vector resistant crops.

Suggested books:

1. Zoonoses: Infectious diseases transmissible from animals to humans. 3rd Edition. 2003. H. Krauss *et al.* ASM Press.
2. Matthews' Plant Virology. 2001. By R. Hull. Academic Press.
3. Service MW (1996) Medical entomology for students. Chapman and Hall
4. Kettle DS (1984) Medical and veterinary entomology CAB international
5. Richard and Davies Imm's general Textbook of Entomology. Vol I & II.. Chapman and Hall.
6. Control of Plant Virus Diseases. By Hadidi*et al.* (Eds). APS. USA.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**3**	**2**	**3**	**3**	**3**	**2**	**3**	**1**	**2**
CO2	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**2**	**2**	**2**	**1**	**2**
CO3	**2**	**2**	**2**	**2**	**1**	**3**	**3**	**2**	**2**	**2**	**1**	**2**
CO4	**1**	**1**	**1**	**-**	**-**	**3**	**3**	**1**	**2**	**1**	**-**	**1**

SEMESTER-IV

VR-401: ANIMAL AND HUMAN VIROLOGY (CORE THEORY)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1. To acquire knowledge on virus-host interactions, host innate and adaptive immune response to viruses, molecular mechanisms of viral pathogenesis,
2. To acquire knowledge on transmission of viruses, mechanism of virus, persistence, infection and spread in the body.
3. To learn the epidemiological concepts and methods of virus diseases, measures of disease occurrence, disease determinants, ecology, epidemiology
4. To learn the surveillance of virus diseases, strategies of virus maintenance in communities, basic concepts, types and patterns of disease survey, prevention, and control methods of viruses.

UNIT-I

Virus-host interactions: Influence of virus on host organism- latent infection, cytopathic effects of viral infections, inclusion bodies, chromosomal aberrations; Response of host cells to viral infection- Host specificity, resistance, interference, immunological responses of the host, host induced modification, patterns of host response-biological gradient, systemic and general syndromes-interactions.

Virus offense meets host defense: Host defense against viral infections, innate and adaptive immune response to viruses.

Molecular mechanisms of viral pathogenesis with respect to poliovirus, rotavirus, herpesvirus (CMV).

UNIT-II

Transmission of viruses: Vertical (Direct) transmission- contact, transplacental, transovarial, sexual, fecal-oral, respiratory; Horizontal (Indirect) transmission- aerosols, fomites, water, food; Vector-arthropod, non-arthropods; Multiple host infections- viral zoonosis.

Persistence of viruses: Pattern of viral infection, mechanism of viral persistence.

Mechanism of infection and viral spread in the body: Routes of entry- skin, respiratory tract, oropharynex and intestinal tract, conjunctiva, genital; Host specificity and tissue tropism- receptors, viral enchancers; Mechanism of virus spread in the body- spread in epithelia, subepithelial invasion and lymphatic spread, spread by the blood stream, invasion of the skin, central nervous system, respiratory and intestinal tracts, other organs.

UNIT-III

Epidemiological concepts and methods of virus diseases: Scope of epidemiology- epidemiological investigation of virus diseases, qualitative and quantitative investigations. Definition of terms, types of epidemiological investigations, components of epidemiology, biological and physical factors influencing the survival and spread of virus diseases.

Describing disease occurrence: Measures of disease occurrence, prevalence, incidence, mapping.

Disease determinants: Host, agent and environment determinants, interactions.

Factors affecting virus ecology and epidemiology: Physical stability and concentration of virus, socio-economic factors, host characteristics- age, sex, morphological and physiological conditions, wild and domestic animals as sources of virus; Physical factors- rainfall, water, wind, air, temperature, soil, seasonal variations.

UNIT-IV

Virus disease surveillance: Types of surveillance, elements and other surveillance methods, evaluation and application of virus surveillance; Quarantine of viral diseases- International and national.

Strategies of virus maintenance in communities: Wild and domestic animals, rural and urban populations.

Surveys: Basic concepts, types of sampling, surveys, collecting information, monitoring vectors, pattern of disease progress.

Prevention and Control of viruses: The infection control policy- aseptic techniques, cleaning and disinfection, protective clothing, isolation; Prevention- sanitation, vector control, vaccines and immunization; Control- chemoprophylaxis, chemotherapy (antiviral drugs, Interferon therapy), efficacy of infection control.

Course Outcomes: At the end of the course the student will be able to

CO1: Understand the virus host interactions, host defense mechanisms against viruses and innate and adaptive immune responses to viruses, molecular mechanisms of viral pathogenesis with respect to polio, rotavirus, and cytomegalovirus.

CO2: Describe the various modes of vertical and horizontal transmission of animal and human viruses, zoonotic virus infections, mechanism of virus persistence, routes of entry and mechanism of virus spread in the body.

CO3: Learn about the epidemiological concepts of virus diseases, measures of disease occurrence, prevalence, and mapping, determinants of disease, factors affecting virus ecology and epidemiology of animal and human viruses.

CO4: Acquire knowledge on virus disease surveillance, strategies of virus maintenance in communities, principles of virus disease survey, methods of prevention and control of animal and human viruses.

Suggested Books:

1. Epidemiology, diagnosis and Management of Zoonses. 2004. K.G. Narayana Sri Kuldeep Sharma Pub.
2. Veterinary Virology. F.A. Murphy *et al.* 1999. 3rd Edition. Academic Press.
3. Medical Virology. 1994. 4th ed. D.O. White and F.Fenner. Academic Press. (chapters–12,13 to 29).
4. Veterinary Virology. 1993. 4th ed. F. Fenner. Academic Press (Part-II).
5. Textbook of Human Virology, 2nd Edition. 1991. R.W. Belshe. Mosby yearbook.
6. Viral Infections of Humans: Epidemiology and control. 1989. 3rd Edition.A.S.Evans (ed). Plenum Medical Book Company.
7. Medical Mirobiology.1997. Fifteenth edition. Edited by D.Green wood, R.C.Slack and J.F.Peutherer. Churchill Lingstone.
8. Medical microbiology.1995. 22nd Edition. G.F. Brooks, J.S.Butel and S.A. Morse. Lange Medical Broks/Mc Graw-Hill.
9. Veterinary Epidemiology. 1986. M. Thrusfield. Butter Worth Publications.
10. Methods in Environmental Virology. 1982. C.P. Gerba and S.M. Goyal. Marcel Dekker Inc.
11. Viruses of vertebrates. 1989. J.S. Porter field, Bailliere Tindals.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	-	2	1	2
CO2	3	3	3	3	2	3	2	1	2	2	1	3
CO3	2	2	2	2	1	3	3	2	2	2	1	2
CO4	1	1	1	2	1	3	3	1	-	1	-	1

VR-402: ANIMAL AND HUMAN VIRUSES AND DISEASES (CORE THEORY)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignments**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1. To describe the etiology, transmission, clinical manifestations, diagnosis, prevention, and control of important (+) sense ssRNA& ds RNAvirusesinfecting animals and humans.

2. To describe the etiology, transmission, clinical manifestations, diagnosis, prevention, and control of important (-) sense RNA virusesinfecting animals and humans
3. To understand the etiology, transmission, clinical manifestations, diagnosis, prevention, and control of important DNA viruses infecting animals and human and
4. To learn about the prion diseases, biology, prevention, and management of major viruses of silkworm, poultry, fish, and prawn, emerging and reemerging virus diseases.

Note: Emphasis should be on etiology, transmission, clinical manifestations, diagnosis, prevention and control.Viral Diseases on the basis of genome and family.

UNIT-I

RNA Viruses:

Picornaviridae-Human Polio, Foot and Mouth disease.**Caliciviridae-** Norwalk virus, Swine Vesicular exanthema.**Coronaviridae-** Avian infectious bronchitis viruses.**Astroviridae-** Human astroviruses.**Coronaviridae-** Human corona viruses.**Togaviridae-** Rubella **Flaviviridae-** West nile, Kyasanur forest disease, Dengue and Japanesencephalities, Bovine viral diarrhea, Hog cholera (classical swine fever). **Reoviridae-** Bovine rotavirus, Blue tongue, Orthoreovirus, African horse sickness.

UNIT-II

Orthomyxoviridae- Animal (swine, horse) influenza.**Paramyxoviridae-** Measles, Mumps, respiratory syncytial, Rinderpest, Canine distemper and Ranikhet disease viruses (Newcastle disease) **Rhabdoviridae-** Rabies, Vesicular stomatitis, Bovine ephemeral fever.**Filoviridae-**Marburg and Zaire Ebola viruses.**Bunyaviridae-**Hantaan, Riftvalley fever and Nairobi sheep disease viruses.**Arenaviridae-** Lymphocytic chorimenangitis virus. Retroviridae – HIV.

UNIT-III

DNA Viruses:

Circoviridae- Chicken anemia virus.**Parvoviridae-** Feline panleukopenia, Canine and Procine parvoviruses.**Poxviridae-** Smallpox, Vaccinia, Sheeppox, Goatpox and Fowlpox viruses. **Herpesviridae-** Human herpes viruses (Varicella-Zoster, Cytomegalo, Epstein-Barr and herpes simplex viruses), Infectious Bovine rhinotrachitis.**Papillomaviridae-** Bovine papilloma viruses.**Adenoviridae-** Human adenoviruses causing respiratory, ocular, genitourinary and enteric infections.Infectious canine hapatitis virus.

UNIT-IV

Hepadnaviridae - Hepatitis-B viruses. **Asfaviridae-** African swine fever virus. **Iridoviridae-** Invertebrate iridescent, Frog iridoviruses.**Polydnaviridae-**Ichonovirus, Bracovirus.**Polyomaviridae-** Polyomavirus. **Papillomaviridae-** Human papilloma viruses.**Parvoviridae-** B19.

Prion diseases: Scrapie of sheep and goat, Bovine spongiform encephalopathy (Mad cow disease).Kuru and CJD of humans

Course Outcomes: At the end of the course the student will be able to

CO1: Acquire the knowledge about etiology, transmission, clinical manifestations, diagnosis, prevention, and control of major RNA viruses of *Picornaviridae, Caliciviridae, Coronaviridae, Togaviridae, Flaviridae*and *Reoviridae.*

CO2: Learn the etiology, transmission, clinical manifestations, diagnosis, prevention, and control of important RNA viruses of *Orthomyxoviridae, Paramyxoviridae, Rhabdoviridae, Filoviridae, Bunyaviridae, Arenaviridae*and*Retroviridae.*

CO3: Describe the etiology, transmission, clinical manifestations, diagnosis, prevention, and control of important DNA viruses of *Circoviridae, Parvoviridae, Poxviridae, Herpesviridae, Papillomaviridae* and *Adenoviridae.*

CO4: Develop the knowledge about etiology, transmission, clinical manifestations, diagnosis, prevention, and control of important DNA viruses belonging to*Hepadnaviridae, Asfaviridae, Iridoviridae, Polydnaviridae, polyomaviridae, Parvoviridae*and understand the biology of prion diseasesof humans.

Suggested Books:

1. Clinical Virology. D.D. Richman *et al.,* 2nd Edition. 2002. ASM Press.
2. Bluetongue. - 2007. Gaya Prasad and Meenakshi Yashpal Singh Mallik. Sri Kuldeep Sharma Pub.
3. Epidemiology, diagnosis and Management of Zoonses. 2004. K.G. Narayana Sri Kuldeep Sha Pub.
4. Foot and mouth disesase –A monograph.2003. S.C. Adhakha Sri Kuldeep Sharma Pub.
5. Veterinary Virology. F.A. Murphy *et al.* 1999. 3rd Edition. Academic Press.
6. Principles of Virology- Molecular biology, pathogenesis and control. 2000. S.J.Flint, L.W.Enquist, R.M.Krug, V.R.Racaniello and A.M.Skalka. ASM press.
7. Veterinary Virology. 1993. 4th ed. F. Fenner. Academic Press (Part-II).
8. Medical Virology. 1994. 4th ed. D.O. White and F.Fenner. Academic Press. (chapters – 12, 29).
9. Viral diseases of animal in India, 1994. S.N,Sharma and S.C. Adlakha, V.S. Bhatt Pub.

10. Textbook of Human Virology, 2nd Edition. 1991. R.W. Belshe. Mosby yearbook.
11. Viral Infections of Humans: Epidemiology and control. 1989. 3rd Edition.
12. A.S.Evans (ed). Plenum Medical Book Company.
13. Medical mirobiology.1997. Fifteenth edition. Edited by D.Green wood, R.C.Slack and J.F.Peutherer. Churchill Lingstone.
14. Medical microbiology.1995. 22nd Edition. G.F. Brooks, J.S.Butel and S.A. Morse. Lange Medical Broks/Mc Graw-Hill.
15. Viruses of vertebrates. 1989. J.S. Porter field, Bailliere Tindals.
16. Encyclopedia of Virology. 1994. R.G. Webster and Allan Granoff. 9eds.) Vol. I, II, Academic Press

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	2	2	3	3
CO2	3	3	3	3	-	3	2	2	1	3	1	2
CO3	2	2	2	-	2	2	3	2	2	2	1	2
CO4	1	1	1	2	-	3	3	1	3	1	-	1

VR-403: PRACTICAL: ANIMAL AND HUMAN VIROLOGY AND ANIMAL AND HUMAN VIRUS DISEASES (CORE-3)

Lecture: 9 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Textbooks, E-learning resources, study materials	
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1. To classify laboratories based on biosafety levels, to understand biosafety, biosecurity, and ethical guidelines to handle viruses in the laboratory and to develop skills to maintain, isolate and quantitate viruses in cell lines and to study their cytopathic effects.

2. To acquire the knowledge on detection ofanimal, human and plant viruses using kit-based point of care tests, preparation, and characterization of virus-based nanoparticles and to participate in extension activities and field, poultry, agriculture research station and aqua form visits.

List of Practicals:

1. Classification of laboratories
2. Preparation of glassware for cell cultures
3. Preparation of buffers and media
4. Collection, filtration, and preservation of calf serum.
5. Culturing of Sheep kidney cells
6. Culturing of Chicken embryo fibroblast cells
7. Sub-culturing of Sheep kidney cells
8. Inoculation of blue tongue virus into sheep kidney cell cultures.
9. Chicken embryo inoculation techniques.
10. Quantal assay of viruses.
11. Study of pathogenic lesions of animal virus diseases through slides
12. Serodiagnosis of virus infections of humans using kits
13. Isolation and analysis of human rotavirus genome
14. Participation in vaccination programs
15. Visits to local poultry, fish and prawn farms

Course Outcomes: At the end of the course the student will be able to

CO1: Understand the biosafety, biosecurity, and ethical guidelines to be followed in the Molecular Virology laboratory.

CO2: Learn the technologies related to preparation of media for cell/tissue cultures, preparation of cell cultures/embryonated eggs for virus cultivation and isolation and quantitation of viruses using differential centrifugation and symptomatology/spectroscopy, respectively.

CO3: Develop skills to test the plant and human viruses using serological and molecular tests and kit-based methods.

CO4: Acquire knowledge on virus-based nanotechnology protocols, virus epidemiology by doing extension activities and visiting field, poultry, agriculture research station and aqua forms.

Suggested books / manuals:

1. Diagnostic Microbiology. 11th Edition. 2002. By B.A. Forbes et al., Mosby publisher.
2. Culture of Animal Cells: A Manual of Basic Technique. 1987. R.I. Freshney. Alan R. Liss. Inc.
3. Virology - A Practical Approach. 1985. D.W.J. Mahy. IRL Press.
4. Virology - A Laboratory Manual. 1992. F.G. Gurleson et al., Academic Press, Inc.
5. Molecular: A Practical Approach. 1993. Edited by A. J. Davson and R.M. Elliott. IRL Press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2	3	2	3	3	2	1	1	3

CO2	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**2**	**2**	**2**	**2**	**2**
CO3	**2**	**2**	**2**	**2**	**1**	**3**	**3**	**3**	**1**	**2**	**-**	**2**
CO4	**1**	**1**	**1**	**2**	**1**	**3**	**3**	**1**	**2**	**1**	**-**	**1**

VR-404 PROJECT WORK (CORE)

Project Work Related to Virology Only-Animal, Human and Plant Virology

Course Educational Objectives:

1.To acquire skills to define and formulate a problem, collection and reviewof literature, hypothesis generation, independently planning of experiments, executing the plans, analysis and evaluation of data, interpretation, and presentation of results of the experiment or investigation in the field of virology.

2. To develop skills to express, communicate and share thoughts, scientific concepts and ideas and experimental results clearly, concisely, and effectively, both in writing and orally and to demonstrate high competence and multidisciplinary subject experience within selected topics related to Virology as a team member and ability to facilitate cooperative or coordinated effort and to contribute to a multidisciplinary team.

Course Outcomes: After completion of the project, the student will be able to

CO1: demonstrate understanding, comprehensive knowledge and skills in various methodological and analytical approaches that are used in contemporary areas of Virology which will make them eligible for higher studies, jobs in various sectors and entrepreneurship abilities.

CO2: Express, communicate and share thoughts, scientific concepts and ideas and experimental results clearly, concisely, and effectively, both in writing and orally.

CO3: Evaluate basic concepts, theories and mechanisms related to Virology based on empirical evidence by following strategic scientific approach to acquire knowledge to find solutions to virus problems related to microbes, plants, animals, and humans.

CO4:Develop ability to review of scientific literature, independently carry out a complete scientific work process, including the understanding of theoretical background, defining, and formulating problems, hypothesis generation, collection, analysis and evaluation of data, and interpretation and presentation of results of an experiment or investigation in the field of Virology.

CO5: Demonstrate high competence and multidisciplinary subject experience within selected topics related to Virology as a team member and ability to facilitate cooperative or coordinated effort and to contribute to a multidisciplinary team.

CP6: Acquire the skill to work independently, identify appropriate resourcesrequired for a project and manage a project through to completion.

CO7:Demonstrate the ability to assess and predict the technological, ethical, and social effects of one's own work /disciplines and of Virology, use ethical practices and avoid unethical behavior such as fabrication, misrepresentation of data or committing plagiarism, not adhering to intellectual property rights, and adopt objective, unbiased and truthful actions in all aspects of work.

CO8:Ability to acquire knowledge and skills that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development and adopt to meet the demands of workplace through knowledge/skill development/reskilling.

VR-404A: CORE PRACTICAL: APPLIED VIROLOGY

Lecture: 6 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Textbooks, E-learning resources, study materials	
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1.To acquire skills in cultivation of plant, animal, and human viruses in plant/animal cell/tissue cultures/embryonated eggs, their isolation, quantification and to understand the role of NPV as biopesticide, purification of virus-based nanoparticles using differential centrifugation.

2. To develop skills to detect the plant and human viruses using serological and molecular detection tests and to participate in extension and field activities to understand the virus epidemiology.

List of Practicals:

1) Preparation of media for animal cell and tissue cultures.
2) Preparation of cell and tissue cultures.
3) Preparation of media for plant tissue culture
4) Cultivation and isolation of virus from cell culture.
5) Cultivation and isolation of animal virus from embryonated chick egg.
6) Application of NPV and its role as biopesticide.
7) Purification of virus-based nanoparticles using differential centrifugation.
8) Characterization of virus-based Nanoparticles
9) Designing and uses of virus like particles (theory-basedexercise)
10) Diagnosis of HBV and HCV using kits.
11) Diagnosis of PRSV using ELISA.
12) Visits to local poultry, fish, and prawn farms.

Course Outcomes: At the end of the course the student will be able to

CO1: Acquire the skills to prepare the cell cultures and embryonated eggs for cultivation of plant, animal and human viruses and to isolate and quantitate viruses.

CO2: Learn the methods to detect plant and animal viruses and able to analyze various types of results obtained from serological and molecular viral diagnostic methods.

CO3: Apply the skills acquired to prepare NPV as biopesticides and virus-based nanoparticles and their isolation using analytical methods.

CO4: Participate in extension activities and field, poultry, agriculture research station and aqua form visits.

Suggested books / manuals:

1. Viruses: Molecular biology, host interactions, and applications to biotechnology. 2018. Paula Tennant, Gustavo Femin and Jerome E Foster. Academic Press.
2. Molecular and Cellular biology of viruses. 2019. Phoebe Lostroh, ISBN 9780815345237.
3. Techniques in diagnoses of Plant Viruses (Plant Pathogens -6)-(2008). Govind.Rao, Rodrigo A. Valverde & C.I. Dovas, Stadium Press.
4. Epidemiology, diagnosis and Management of Zoonses. (2004). K.G. Narayana Sri Kuldeep Sharma Pub.
5. Field's Virology. (2002). Vol. I, II.
6. Bailey and Scotts' Diagnostic Microbiology. 11th Edition. (2002). By B.A. Forbes et al., Mosby publisher.
7. Clinical Virology. (2002). 2nd edition. D.D. Richman et al., ASM
8. Principles of gene manipulation. 6th edition. (2002). By S. Primrose, R. Twyman and B. Old. Blackwell Science.
9. Matthews' Plant Virology. (2001). By R. Hull. Academic Press.
10. Principles of Virology- Molecular biology, pathogenesis and control. (2000). S.J.Flint, L.W. Enquist, R.M. Krug, V.R. Racaniello and A.M. Skalka. ASM press.
11. Control of Plant Virus Diseases. By Hadidi*et al.* (Eds). APS. USA.
12. Medical Virology. (1994). 4th ed. D.O. White and F. Fenner. Academic Press.
13. Veterinary Virology. (1993). 4th ed. F. Fenner*et al.,* Academic Press (Part-II).

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	2	3	3	3	2	2	1	3
CO2	3	3	3	2	2	2	2	2	2	2	-	2
CO3	2	2	2	2	1	3	2	2	-	2	1	-
CO4	1	1	1	1	3	3	3	1	2	1	-	1

(OR)

VR-404: CORE PRACTICAL:TUMOR BIOLOGY AND VIROLOGY

Lecture: 6 hours/week	**Semester End Examination: 100 Marks**
Tutorial: Textbooks, E-learning resources, study materials	
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1. To detect carcinogens and mutagens using standard tests, to observe histopathology of animal viruses associated with tumors and to detect tumor viruses by PCR.

2. To cultivate poultry tumor viruses in cell cultures, to determine the effect of antiviral compounds on transformed cell lines, cell viability assays and to diagnose HCV and HPV using commercial point-of care kit-based tests.

List of Practicals:

1) Detection of carcinogens and mutagens using Ames Test
2) Histopathology of animal tumor viruses (specimens and slides)
3) Detection of tumor viruses using PCR
4) Observation of specimens (visiting Veterinary University and SVIMS).
5) Cell viability test
6) MTT assay
7) Cell culture and cultivation of Chicken/bird tumor viruses
8) Diagnosis of HCV, HIV and HPV using commercial kits
9) Preventive and control measures of tumor viruses (theory exercises)

Course Outcomes: At the end of the course the student will be able to

CO1: Acquire skills to detect carcinogens and mutagens using standard tests such as Ames test.

CO2: Distinguish transformed and normal cell lines and determine the anticancer property of biologically active compounds.

CO3: Design and execute PCR and other point of care methods using commercial kits for detection of tumor viruses (HCV, HIV, HPV).

CO4: Perform cultivation of poultry tumor viruses in cell cultures and acquiring the knowledge on histopathology of animal tumor viruses.

Suggested books / manuals:

1. Manual of Clinical Oncology Paperback – Dec 2017, by Chmielowski (Author), 900 pges, Publisher: Wolters Kluwer India Private Limited; Eighth edition (2017), price
2. Devita et al (2011), Cancer, Principles and Practice of Oncology: Review 4 by Govindan
3. CBS Oncology entrance examination (PB 2017) by BHATIA M.S. P.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	2	3	3	3	3	2	3	2	3
CO2	3	3	3	3	2	-	2	2	2	1	3	1
CO3	2	2	2	1	1	-	3	2	-	2	1	2
CO4	1	1	1	3	2	3	3	1	2	1	-	2

VR-405: a) APPLIED VIROLOGY (GENERIC ELECTIVE)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignments**
Tutorial:Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1. To learn about the basic concepts, requirements and methods of plant and animal cell and tissuecultures
2. To acquire knowledge about the production and applications of recombinant DNA technology-based antibodies and vaccines to viruses, production of virus-resistant crops and virus-based biopesticides.
3. To acquire knowledge about common virus infections caused to human beings through vectorand non-vector borne modes and basic principles of biosafety, biosecurity, and ethical/regulatory issues in Virology
4. To understand the concepts of using virus based genetic resources and model systems in molecular biology, phage display and therapy technologies and viruses as biological weapons.

UNIT – I

Cell culture methods: Principles of plant and animal cell and organ culture technologies for cultivation and propagation of viruses and for production of Mabs. .

Antibodies: Production of conventional and rDNA technology based polyclonal and monoclonal antibodies to viruses and their applications.

Diagnostic virology: Collection, transport and processing of samples. Biological, Physical, Chemical, immunological and molecular approaches for identification and diagnosis of plant and animal and human viruses.

UNIT-II

Public health Virology: Biology, prevention and control of common nosocomial, enteric (food and water-borne, hepatitis A & E, polio, rotaviruses), blood-borne (hepatitis B & C, HIV), contact transmitted (common cold, flu) and insect-borne (Japanese encephalitis, dengue, chikungunya) viruses

Major viruses of silkworm, poultry, fish and prawn: Biology, prevention and management

Emerging and reemerging animal and human viruses: HIV, SARS, avian flu, swine flu, Marburg and Ebola viruses.

Vaccines to viruses: Type of immunization procedures, active and passive immunization, designing of vaccines, classical and novel/modern approaches for the production of vaccines, purified macromolecules as vaccines, Recombinant – vector vaccines, DNA vaccines, Synthetic peptide vaccines, Multivalent sub-unit vaccines, uses of vaccines, benefits of vaccination, mass immunization programs.

UNIT-III

Selection of virus-free plant propagules (seeds, vegetative propagules): Sampling and large scale screening of materials and certification.

Virus-free plants: Production and mass multiplication of virus-free field and horticultural crops and ornamental plants by tissue culture technologies.

Virus resistant / tolerant crops: Production of virus resistant / tolerance crops through transgenic technology by exploiting genes derived from viruses, natural resistant plants and from other sources. Guidelines for testing and field release of transgenic crops in India.

Emerging and reemerging plant viruses: Gemini-, tospo-, ilar- , badna- and nanoviruses.

UNIT-IV

Viruses as molecular model systems in Biology and Molecular Biology: Viral nucleic acids as genetic materials. Exploitation of viruses as model systems in the development of new technologies in biology.

Viruses as unique genetic resources: Exploitation of viral genes / sequences in the construction of varied types of gene vectors (cloning, shuttle, expression and transcription) and their applications. Virus genes as a source of navel enzymes, gene expression activators and silencers.Molecular model systems in understanding the replication of nucleic acids and regulation of gene expression strategies and cancer biology (SV-40, adeno and papillomaviruses).Display of foreign peptides on virion surface and applications.

Viruses as biocontrol agents (viral biopesticides): Bacterial, algal, fungal and insect viruses – mass production and their application as biocontrol agents against bacterial and fungal pathogens of plants, algae and insect pests.

Phage therapy: Isolation, identification and exploitation of promising bacteriophages to control bacterial infections in humans.

Gene therapy: Exploitation of viruses (retro-, adeno- and parvoviruses) as functional gene delivery systems.

Viruses as biological warfare, biocrime and bioterrorism agents: Small poxvirus (variola), viral encephalitis and viral hemorrhagic fevers; HIV, viral hemorrhagic fevers (Ebola) and yellow fever virus.

Exploitation of viruses for nano biotechnological applications

Course Outcomes: At the end of the course the student will be able to

CO1: Understand the basic concepts, types, requirements and methodologies of plant/animal cell and tissue cultures used for cultivation of plant and animal viruses.

CO2: Learn the production of recombinant DNA technology-based antibodies and vaccines to viruses and the concepts and production of virus resistant/tolerant crops and virus-based biopesticides.

CO3:Acquire knowledge about common virus infections caused to human beings through vector and non-vector borne modes and basic principles of biosafety, biosecurity, and ethical/regulatory issues in Virology and basics in Intellectual Property Rights (IPR).

CO4:Understand the utilization of viruses as viral genes/sequences as unique genetic resources, novel enzymes, gene expression activators and silencers, gene delivery systems, epitope display platforms and model systems in understanding the replication of nucleic acids and regulation of gene expression strategies and cancer biology, phage display and therapy technologies and viruses as biological weapons.

Suggested books:

1. Viruses: Molecular biology, host interactions, and applications to biotechnology. 2018. Paula Tennant, Gustavo Femin and Jerome E Foster. Academic Press.
2. Molecular and Cellular biology of viruses. 2019. Phoebe Lostroh, ISBN 9780815345237.
3. Techniques in diagnoses of Plant Viruses (Plant Pathogens -6) -(2008). Govind.Rao, Rodrigo A. Valverde & C.I. Dovas, Stadium Press.
4. Epidemiology, diagnosis and Management of Zoonses. (2004). K.G. Narayana Sri Kuldeep Sharma Pub.
5. Field's Virology. (2002). Vol. I, II.
6. Bailey and Scotts' Diagnostic Microbiology. 11th Edition. (2002). By B.A. Forbes et al., Mosby publisher.
7. Clinical Virology. (2002). 2nd edition. D.D. Richman et al., ASM
8. Principles of gene manipulation. 6th edition. (2002). By S. Primrose, R. Twyman and B. Old. Blackwell Science.
9. Matthews' Plant Virology. (2001). By R. Hull. Academic Press.
10. Principles of Virology- Molecular biology, pathogenesis and control. (2000). S.J.Flint, L.W. Enquist, R.M. Krug, V.R. Racaniello and A.M. Skalka. ASM press.
11. Control of Plant Virus Diseases. By Hadidi*et al.* (Eds). APS. USA.
12. Medical Virology. (1994). 4th ed. D.O. White and F. Fenner. Academic Press.
13. Veterinary Virology. (1993). 4th ed. F. Fenner*et al.,* Academic Press (Part-II).

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**3**	**3**	**3**
CO2	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**2**	**2**	**2**	**1**	**2**
CO3	**2**	**2**	**2**	**2**	**1**	**3**	**3**	**-**	**3**	**1**	**2**	**2**

CO4	**1**	**2**	**1**	**3**	**2**	**3**	**3**	**1**	**2**	**-**	**-**	**1**

(OR)

VR-405: TUMOR BIOLOGY AND VIROLOGY (GENERIC ELECTIVE)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1. To understand basic concepts, principles and methods of cell and organ cultures, cell cycle and its regulation, cell signaling pathways and apoptosis
2. To acquire knowledge on basic aspects of tumors, molecular mechanisms of tissue transformation, tumorigenesis, carcinogenesis, and chromosomal abnormalities.

3. To learn about oncogenes and tumor suppressor genes, and different RNA and DNA viruses causing tumors, viral oncogenes, viral mechanisms for inducing tumors, immune responses to tumors,immune therapy and tumor therapy strategies.

4.To learn about DNA viruses causing tumors, viral oncogenes, viral mechanisms for inducing tumors, immune responses to tumors,immune therapy and tumor therapy strategies.

UNIT-I

Eukaryotic cell Biology: Principles of cell and organ culture techniques. Cell culture repositories.Storage and revival of cell cultures.Cell cycle and growth regulation, cyclins.Cell-to-cell signaling pathways and mechanisms.Intracellular signaling.Apoptosis.

UNIT-II

Tissue transformation and tumorogenesis: Plants-Induction of galls / tumors by *Agrobacterium* and viruses. **Animals-**Terminology, types of tumors. Experimental approaches to study transformation and tumorogenesis. Stages of transformation and tumorogenesis.Differences between normal and transformed cells.Control of cell proliferation.

Carcinogens and carcinogenesis: Physical, chemical and biological carcinogens. Screening of carcinogens.Molecular mechanisms of carcinogenesis.

Chromosome abnormalities in neoplasms: Translocation, amplification, deletion of oncogenes and consequences.

UNIT-III

Oncogenes: Cellular / proto-oncogenes, viral oncogenes. Antioncogenes / tumor suppressor genes: discovery, Characterization, and their role in tumor supression. Gene products and their role in cell cycle and growth regulation.
RNA Viruses: Retroviruses implicated in causing tumors in animals and humans. Tracing of origin of retroviral oncogenes.Viral oncogene products and their role in tumorogenesis.Activation of expression of cellular genes by retroviruses.Viral genetic information in transformed cells.
Hepatitis-C virus associated with hepatocellular carcinoma.

UNIT-IV
DNA Viruses: Members of *Adeno-*, *Hepadna-*, *Herpes-*, *Papilloma-*, *Polyoma- and Poxviridae.* Transforming gene products and functions of adenoviruses, papillomaviruses and polyomaviruses. Transformation by activation of cellular signal transduction pathways. Transformation via cell cycle control pathways. Other mechanisms of transformation and oncogenesis.
Tumor suppressor genes / antioncogenes: Discovery, characterization, and their role in tumor suppression.
Tumor immunology: Cancer and the Immune system, tumor specific antigens, tumors of the immune system, immune responses to tumors, cancer immunotherapy.
Tumor therapy: Physical (radiation), chemical and immunotherapy. Angiogenesis and inhibitors of angiogenesis.Gene therapy.

Course Outcomes: At the end of the course the student will be able to

CO1: Acquire knowledge about the basic aspects of tumors, distinguish normal and transformed cells and describe the role of oncogenes and tumor suppressor genes in causing cancers.

CO2: Understand the role and mechanism of carcinogens in inducing carcinogenesis and molecular viral mechanisms of transformation and tumorigenesis.

CO3: Describe the role of oncogenes, tumor suppressor genes, viral oncogenes, types, and mechanism of RNA viruses in inducing tumors.

CO4: List the DNA viruses causing tumors and learn their tissue transformation mechanisms, role of tumor suppressor genes in tumor suppression, immune mechanisms against tumors, immunotherapy, and physical and chemical therapeutic interventions against tumors.

Suggested books:

1. The Cell – A molecular approach. Fourth edition-2007. G. M. Cooper &R.E.Hausman. ASM Press.
2. Cell signaling. Second edition-2005. John T. Hancock. Oxford University press
3. The World of the Cell. 5th Edition. 2003. By Becker, Kleinsmith and Hardin. Pearson Education.
4. Culture of Animal Cells: A Manual of Basic Technique. 1987. R.I. Freshney. Alan R. Liss. Inc.
5. Fields Virology. 2001. 3rd Edition. Vol. 1, 2. B.N. Fields, D.M. Knipe, P.M. Howley.
6. Oncogenes. 1995. 2nd Edition. By G.M.Cooper. Jones and Bartlet publishers.
7. Principle of Virology: Molecular Biology, pathogenesis and control of animal viruses. 2004. By S.J. Flint *et al.* ASM press.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3	3	3	3	3	3	3	2	3	1	3
CO2	3	3	3	2	-	2	2	2	1	1	-	3
CO3	2	2	2	2	1	-	2	2	2	2	1	1
CO4	1	1	1	1	-	3	3	1	1	1	2	-

VR-406: CLINICAL VIRIOLOGY (OPEN ELECTIVE)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assginements**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1. To learn about basic concepts of taxonomy, morphology, transmission, cultivation and replicationand characterization of viruses
2. To understand methods used for sample collection, preservation, and detection of viruses and GMP and biosafety practices used in the clinical laboratories.

3.To acquire knowledge aboutEpidemiology principles, describing disease occurrence, disease surveillance and control strategies, modern vaccinology.

4. To acquire knowledge about clinically important food-borne, blood borne, vector borne, and contact borne, and zoonotic diseases and strategies used for their prevention and control.

UNIT-I

Introduction to Virology; Characteristics and Replication of Viruses, Different methods to study viruses, virus isolation, serology techniques, molecular techniques

UNIT-II

Viral Specimen collection and processing, diagnosis of Viral Infections; laboratory biosafety and quality control.

UNIT-III

Epidemiology principles, describing disease occurrence, disease surveillance and control strategies, modern vaccinology.

UNIT-IV

Poliomyelitis and other enterovirus infections; Herpesviruses; poxviruses, lyssavirus and rabies, Arthropod-borne viruses, Rubella-postnatal infections; filoviruses and Arenaviruses, rotaviruses; Hepatitis viruses, Papovaviruses; Retroviruses and AIDS; Unconventional slow viruses, prions.

Course Outcomes: At the end of the course the student will be able to

CO1: Acquire basic understanding of virus properties, virus replication and learn methods of virus isolation and characterization of viruses using serological and molecular techniques.

CO2: Learn to collect, preserve the virus samples, and detect the viruses using biological, serological, and molecular methods, laboratory biosafety and quality control practices.

CO3: Understand the principles of epidemiology, disease occurrence patterns, disease surveillance and control strategies,concept, and methods of modern vaccines to viruses.

CO4: Learn about the approaches used for prevention and control of clinically important infectious caused by human viruses, unconventional slow viruses, and prions.

Suggested References:

1. *Principles and Practice of Clinical Virology* , Carol Shoshkes Reiss, 2009.Editor:**,** 6th ed. ISBN: 9780470517994. $450 p. 968.
2. Clinical Virology. D.D. Richman *et al.,* 2nd Edition. 2002., ASM Press.
3. Principles of Virology- Molecular biology, pathogenesis and control. 2000. S.J.Flint, L.W.Enquist, R.M.Krug, V.R.Racaniello and A.M.Skalka. ASM press.
4. Fields Virology. 2001. 3rd Edition. Vol. 1, 2. B.N. Fields, D.M. Knipe, P.M. Howley.

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**3**	**3**	**3**	**3**	**2**	**3**	**2**	**3**	**2**	**1**	**3**	**3**
CO2	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**-**	**2**	**-**	**-**
CO3	**2**	**2**	**2**	**-**	**-**	**3**	**3**	**2**	**-**	**2**	**2**	**2**
CO4	**1**	**1**	**1**	**1**	**2**	**2**	**3**	**1**	**2**	**1**	**1**	**1**

(OR)

VR-406: EMERGING INTECTIOUS VIRAL DISEASES (OPEN ELECTIVE)

Lecture: 5 hours/week	**Internal Assessment: 20 Marks** **Seminars and assignements**
Tutorial: Textbooks, E-learning resources, study materials, PowerPoint lectures	**Semester End Examination: 80 Marks**
Semester: IV	**Credits: 4 Credits**

Course Educational Objectives:

1. To understand the evolution, epidemiology, emergence of infectious and emerging virus diseases, viral zoonotic infections
2. To learn about HIV, SARS, and host defence mechanisms against infectious diseases.
3. To learn about the biology, diagnosis and management of vector-borne emerging infectious viral diseases
4. To understand the impact of environment on virus emergence, control strategies followed for emerging virus diseases and bioterrorism.

UNIT-I

Evolution, epidemiology and emergence of infectious viral diseases, Biology of Emerging Infectious Diseases, zoonotic infections

UNIT-II

Human Immunodeficiency virus, SARS, and Influenza; host defences against infectious diseases

UNIT-III

Vector-borne emerging infectious viral diseases- Dengue & Haemorrhagic Fever Viruses, chikungunya virus, west Nile virus, Ebola virus, Zika virus

UNIT-IV

Impact of social and environmental change on emergence, Controversies, vector control, and anti-virulence therapies, vaccines, public health measures, Bioterrorism.

Course Outcomes: At the end of the course the student will be able to

CO1: Understand the evolution, biology, epidemiology, and emergence of infectious virus diseases, biology of emerging infectious diseases, zoonotic infections

CO2:Learn about the biology, clinical symptoms, epidemiology, diagnosis, and control of viruses causing AIDS and SARS and host defense mechanisms against infectious virus diseases.

CO3:Describe the biology, clinical symptoms, epidemiology, diagnosis, and control of vector borne emerging infectious viral diseases.

CO4:Acquire knowledge on impact of social and environmental change on emergence of viruses, vector control and antiviral therapies, vaccines, public health measures and bioterrorism.

Suggested References:

1. Clinical Virology. D.D. Richman *et al.*, 2nd Edition. 2002. ASM Press.
2. Epidemiology, diagnosis and Management of Zoonses. 2004. K.G. Narayana Sri Kuldeep Sharma Pub.
3. Veterinary Virology. F.A. Murphy *et al.* 1999. 3rd Edition. Academic Press.
4. Principles of Virology- Molecular biology, pathogenesis and control. 2000. S.J.Flint, L.W.Enquist, R.M.Krug, V.R.Racaniello and A.M.Skalka. ASM press.

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO1	**3**	**3**	**3**	**2**	**3**	**2**	**3**	**2**	**3**	**3**	**3**	**3**
CO2	**3**	**3**	**2**	**3**	**1**	**3**	**2**	**-**	**2**	**2**	**-**	**-**
CO3	**2**	**2**	**2**	**1**	**1**	**-**	**-**	**2**	**-**	**1**	**1**	**2**
CO4	**1**	**1**	**1**	**2**	**3**	**3**	**3**	**-**	**2**	**1**	**2**	**1**

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