University of Pune

M. Sc. (Microbiology)
Revised Syllabus
For
Credit and Semester Based
Post Graduate Course in Microbiology

w.e.f July 2013

Preamble:

Overall picture of student trends (before undergraduate studies) in selecting courses is very typical; most of the science students aim at professional courses, particularly leading to studies in Engineering. Comparatively less number of students opts for degrees in Biosciences. For several years now, the first preference of students desiring to enter the field of Life Sciences has been Microbiology, and for last 2 to 3 years it has shifted partly to Biotechnology courses. Both these disciplines viz. Microbiology and Biotechnology deal with overlapping interests. Microbial sciences focus more on study of the microbial world (this limitation needs to be corrected!) while Biotechnology focuses more on application of mammalian systems. The main theme of teaching these courses, however, remains the same i.e. application of basic principles of Life Science to develop into technology. Modern biology combines the principles of chemistry and biological sciences (molecular and cellular biology, genetics, and immunology) with technological disciplines (engineering, computer science) to produce goods and services and for environmental management. Tools of molecular biology play an important role in preparation of an engineered clone, a recombinant or a genetically manipulated organism (GMO). The Board of Studies in Microbiology has identified the following thrust areas and prospective plans for syllabi reforms at postgraduate level:

- **Microbial Technology** – includes application of bacteria, fungi, protozoa and viruses in traditional (food, dairy, wine, antibiotics, fermentation, etc.) and biotechnological industries.
- **Human health** – includes pathogenic micro-organisms (bacterial, viral, protozoan and fungal), therapeutics and pharmaceutical approach towards diseases, diagnostics, vaccine developments, epidemiological characterization of diseases, gene therapy, etc.
- **Agriculture** – includes biofertilizers and biocontrol, ecology and geomicrobiology.
- **Environment** – includes cleaner processes that produce less waste and use less energy and water in such industrial sectors as chemicals, pulp and paper, textiles and dyes, food, energy, and metals and minerals, harnessing microbial utilities avoiding the use of caustic chemicals, bioremediation and bioprospecting
- **Microbial diversity** – includes collecting information of diversity, exploration and utilization of diversity to identify and harvest biomolecules for human health improvisation, micro-organisms from extreme environments, Archeabacteria, etc.
- **Research in life-sciences** – includes research tools like immunology and molecular biology, developmental biology, evolution, stem cell research, etc.

  To enrich students' knowledge and train them in the above mentioned areas; we feel certain topics in the present syllabus need to be supplemented and strengthened by inclusion of few additional topics. Areas that need to be introduced in syllabi have been identified as:

  - Eukaryotic cellular organization
  - Eukaryotic gene expression e.g. yeast genetics
  - Determinants of microbial pathogenecity
  - Immunopathology, immunopharmacology and cancer biology
  - Protein stability, conformation and folding
  - Over-expression of recombinant proteins
  - Biocontrol
  - Bioinformatics
  - Molecular tools for characterization, identification of bacteria
  - Possible utilization of microbial population from extreme environments

In addition, we feel that the students should be well acquainted with research methodology which includes different skill developments in scientific writing, data handling and processing, development of research ideas and planning / designing of research projects. The skill sets thus evolved will help the students in academic and applied research.

Introduction:

The syllabi till today had been sufficient to cater for the needs of students for building up their careers in industry and research. However, with the changing scenario at local and global level, we feel that the syllabus orientation should be altered to keep pace with developments in the education sector. The need of the hour is proper syllabi that emphasize on teaching of technological as well as the administrative aspects of modern biology. Theory supplemented with extensive laboratory expertise will help these students, to avail these opportunities. Both these aspects i.e. theory and more of practical needs to stressed, such that a post-graduate student can start work directly in applied fields (industry or institutions), without any additional training.

Thus, the university / college itself will be developing the trained and skilled man-power. We even find a lack of trained teachers who can share their experiences on different aspects in microbiology. And we plan to restructure the syllabus in this viewpoint. The restructured syllabus will combine the principles of chemistry and biological sciences (molecular and cell biology, genetics, immunology and analytical tools) with technological disciplines to produce goods and services and for environmental management.

Microbiology curricula are operated at two levels viz. undergraduate and postgraduate. The undergraduate curricula are prepared to impart basic knowledge of the respective subject from all possible angles. In addition, students are to be trained to apply this knowledge particularly in day-to-day applications of Microbiology and to get a glimpse of research.

Objectives to be achieved:

- To enrich students' knowledge and train them in the pure microbial sciences
- To introduce the concepts of application and research in Microbiology
- To inculcate sense of scientific responsibilities and social and environment awareness
- To help students build-up a progressive and successful career

Eligibility

B. Sc. with Principle subject Microbiology. The concerned centers may conduct their own entrance examination, for admission.

Duration of Course – Two years.

External students – There shall be no external students.

Course Structure –

There shall be four semesters, at each semester there will be 3 theory courses and 2 practical courses. In each theory course there shall be 3 core / compulsory credits (TC) and students will take 2 noncore / optional credits (TN). Each practical course shall have 5 core / compulsory credits (PC).

Credit Distribution per semester

Core (compulsory) 75%		Non-core (optional) 25%	Total credits per semester (100%)
Theory	**Practical**		
09	10	6 (2 per course)	25

Workload:

There shall be 15 contact hours per credit (1 hour / credit / week), out of which classroom teaching hours will be 12 and 3 contact hours for preparation of in-semester continuous assessment.

Semester I

Semester I		
Paper Title	**Credit Code**	**Credit title**
MB 501: Microbial Diversity & Taxonomy	1.01 TC	Concept of speciation and species evolution
	1.02 TC	Microbial diversity
	1.03 TC	Taxonomy of Bacteria and Introduction to Bergey's Manuals
	1.04 TN	Taxonomy of Fungi
	1.05 TN	Exploration of unculturable bacteria
	1.06 TN	Theories of Evolution
	1.07 TN	Gene Sequencing
MB 502: Quantitative Biology	1.08 TC	Descriptive Statistics
	1.09 TC	Testing of Hypothesis - I
	1.10 TC	Testing of Hypothesis - II
	1.11 TN	Introductory Biostatistics
	1.12 TN	Probability and Probability Distributions
	1.13 TN	Designing of Experiments
	1.14 TN	Modeling in Biology
MB 503: Cell Organization and Biochemistry	1.15 TC	Biochemistry of Proteins and Nucleic acid
	1.16 TC	Ultrastructure and Organization of Eukaryotic Cell
	1.17 TC	Development and Differentiation
	1.18 TN	Communication And Coordination among microorganisms
	1.19 TN	Bioorganic Chemistry
	1.20 TN	Carbohydrate and lipid biochemistry
	1.21 TN	Biochemical role of Micronutrients
	1.22 TN	Hormones and their function
MB 511: Practical Course 1: Microbial Diversity & Systematics	1.23 PC	Isolation and identification of Eubacteria
	1.24 PC	Isolation and identification of Fungi
	1.25 PC	Isolation and identification of Cyanobacteria
	1.26 PC	Molecular Taxonomy
	1.27 PC	Research Methodology - I
MB 512: Practical Course 2: Cell Biology & Biochemistry	1.28 PC	Biochemistry-I
	1.29 PC	Biochemistry- II
	1.30 PC	Cell Biology-I
	1.31 PC	Cell Biology-II
	1.32 PC	Biostatistics

Semester II

Semester II		
Paper Title	**Credit Code**	**Credit title**
MB 601: Instrumentation & Molecular Biophysics	2.01 TC	Biomolecular Separation and Detection
	2.02 TC	Spectroscopies of Biomolecules
	2.03 TC	Biophysical Techniques
	2.04 TN	Protein Structure and Folding
	2.05 TN	Tools of Bioinformatics
	2.06 TN	Synthesis and Characterization of Bio-Nanoparticles
MB 602: Virology	2.07 TC	Structure and Replication of viruses
	2.08 TC	Cultivation and Detection methods for viruses
	2.09 TC	Nomenclature & Classification systems of viruses
	2.10 TN	Bacteriophages
	2.11 TN	Viral Therapeutics
	2.12 TN	Animal Viral Diseases
	2.13 TN	Plant Viral Diseases
MB 603: Microbial Metabolism	2.14 TC	Enzyme Kinetics
	2.15 TC	Bioenergetics
	2.16 TC	Aerobic and anaerobic respiration
	2.17 TN	Membrane Transport
	2.18 TN	Nitrogen metabolism
	2.19 TN	Photosynthesis
	2.20 TN	Biosynthesis of carbohydrates in plants and bacteria
	2.21 TN	Lipid biosynthesis
MB 611: Practical Course 1: Biophysics & Virology	2.22 PC	Biophysical Instrumentation – I
	2.23 PC	Biophysical Instrumentation - II
	2.24 PC	Virology (Plant Viruses)
	2.25 PC	Virology (Animal & Bacterial Viruses)
	2.26 PC	Research Methodology – II
MB 612: Practical Course 2: Enzymology & Microbial Metabolism	2.27 PC	Purification & Assay of Enzymes
	2.28 PC	Isolation and characterization of anaerobic bacteria
	2.29 PC	Microbial metabolism-I
	2.30 PC	Microbial Metabolism-II
	2.31 PC	Extraction, detection and characterization of aflatoxins

General Instructions

The post-graduate degree will be awarded to students who obtain a total 100 credits (25 average credits per semester). Except practical credits wherever applicable, students may be allowed to obtain less courses per semester on a condition that they complete the degree in a maximum of four years. This facility will be available subject to the availability of concerned courses in a given semester and with a maximum variation of 25 % credits (in case of fresh credits) per semester.

One credit will be equivalent to 15 clock hours of teacher-student contact per semester.

Among the total number of credits required to be completed for Post-Graduate degree course (100 credits) students have to opt for minimum 75% credits from parent department and remaining 25% can be opted from either parent department or other department/centers/faculty. In addition to that, students have to obtain compulsory credits over and above.

Assessment shall consist of
a) In-semester continuous assessment
and
b) End-semester assessment

both shall have an equal weightage of 50% each.

The teacher concerned shall announce the units for which each in-semester assessment will take place. However, the end-semester assessment shall cover the entire syllabus prescribed for the course.

An in-semester assessment of 50% marks should be continuous and at least two tests should be conducted for courses of 4 credits and a teacher must select a variety of procedures for examinations such as:

1. Written test and/or mid term test (not more than one or two for each course)
2. Term paper
3. Journal/Lecture/Library notes
4. Seminar presentation
5. Short Quizzes
6. Assignments
7. Extension work
8. An open book test (with the concern teacher deciding what books are to be allowed for this purpose)
9. Mini research project by individual student or group of students

The concerned teacher in consultation with the Head of the PG Department shall decide the nature of questions for the unit test.

Semester end examination for remaining 50% marks will be conducted by University of Pune.

The student has to obtain 40% marks in the combined examination of In-semester assessment and Semester-End assessment with a minimum passing of 30% in both these separately.

To pass the degree course, a student shall have to get minimum aggregate 40% marks (E and above grade point scale) in each course.

If a student misses an internal assessment examination he/she will have a second chance with the permission of the Principal in consultation with the concerned teacher. Such a second chance shall not be the right of the student.

Internal marks will not change. A student cannot repeat Internal assessment. In case he/she wants to repeat internal assessment he/she can do so only by registering for the said course during the 5^{th} / 6^{th} semester and onwards up to 8^{th} semester.

Students who have failed semester-end exam may reappear for semester-end examination only twice in subsequent period. The students will be finally declared as failed if he/she does not pass in all credits within a total period of four years. After that, such students will have to seek fresh admission rules prevailing at that time.

A student cannot register for the third semester, if she/he fails to complete 50% credits of the total credits expected to be ordinarily completed within two semesters.

There shall be Revaluation of answer scripts of semester examination but not of internal assessment papers as per the Ordinance no. 134 A and B.

While marks will be given for all examinations, they will be converted into grades. The semester end grade sheets will have only grades and final grade sheets and transcripts shall have grade points average and total percentage of marks (up to two decimal points). The final grade sheet will also indicate the PG center to which candidate belongs.

Each assessment/test will be evaluated in terms of grades. The grades for separate assignments and the final (semester-end) examination will be added together and then converted into a grade and later a grade point average. Result will be declared for each semester and the final examination will give total grades and grade point average.

Marks/Grade/Grade points

Marks	**Grade**	**Grade Points**
100 to 75	O: Outstanding	06
74 to 65	A: Very Good	05
64 to 55	B: Good	04
54 to 50	C: Average	03
49 to 45	D: Satisfactory	02
44 to 40	E: Pass	01
39 to 0	F: Fail	00

Final Grade Points:

Grade Points	**Grade**
05.00-06.00	O
04.50-04.99	A
03.50-04.49	B
02.50-03.49	C
01.50-02.49	D
00.50-01.49	E
00.00-00.49	F

The formula for GPA will be based on weighted Average. The final GPA will not be printed unless a student passes courses equivalent to minimum 100 credits.

Semester Grade Point Average (SPGA) =

$$SPGA = \frac{\sum_{i=1}^{p} CiGi}{\sum_{i=1}^{p} Ci}$$

$$SPGA = \frac{\Sigma \text{ Grade points Earned} \quad X \quad \text{Credits for each course}}{\text{Total credits}}$$

Cumulative Grade Points Average (CGPA) =

$$CPGA = \frac{\sum_{i=1}^{p} CiGi}{\sum_{Z=1}^{p} Ci}$$

$$CPGA = \frac{\Sigma \text{ Total Points Earned} \quad X \quad \text{Credits for each course}}{\text{Total credits}}$$

'B' grade is equivalent to atleast 55% of marks as per circular No. UGC-1298/[4619]UNI-4 dated December 11, 1999.

If the GPA is higher than the indicated upper limits in the three decimal digits, then the student be awarded higher final grade (e.g. a student getting GPA of 4,492 may awarded 'A').

There will be final compilation and moderation at GPA (final) level done at the Department. While declaring the result, the existing relevant ordinances are applicable. There is also a provision for verification and revaluation in case of verification, the existing rules will be applicable. The revaluation result will be adopted if there is a change of at least 10% marks and in the grade of the course.

For grade improvement a student must reappear for semester end examination for a minimum 30 credits. These courses will be from parent department. Grade improvement programme will be implemented at the end of the academic year. A student can opt for the grade improvement programme only after the declaration of final semester examination (i.e. at the end of the next academic year after passing the M.Sc. examination and within two years of completion of M.Sc. only once).

Grade proposed norms:

O: Outstanding: Excellent analysis of the topic, (75% and above)
Accurate knowledge of the primary material, wide range of reading, logical development of ideas, originality in approaching the subject, Neat and systematic organization of content elegant and lucid styl;

A: Very Good: Excellent analysis of the topic (65 to 74%)
Accurate knowledge of the primary material, acquaintance with seminal publications, logical development of ideas, Neat and systematic organization of content, effective and clear expression;

B: Good: Good analysis and development of topic (55 to 64%)
Basic knowledge of the primary material, logical development of ideas, Neat and systematic organization of content, effective and clear expression;

C: Average: Some important points covered (50 to 54%)
Basic knowledge of the primary material, logical development of ideas, Neat and systematic organization of content, good language or expression;

D: Satisfactory: Some points discussed (45 to 49%)
Basic knowledge of the primary material, some organization, acceptable language or expression;

E: Pass: Any two of the above (40 to 44%)

F: Fail: None of the above (0 to 39%)

Members, Sub-committee for M. Sc. Microbiology Syllabus
Members, Board of Studies in Microbiology
May, 2013.

M.Sc. Microbiology Syllabus (To be implemented from)
Credit and Semester System

Semester I

MB 501 - Microbial Diversity and Taxonomy

Credit No.	Credit Title and Contents	References
1.01 TC	**Concept of speciation and species evolution**	
	• Differences in concept of 'species' in eukaryotes and prokaryotes. • Definition of species in prokaryotes. • Types of 'species' • Evolution of species and concepts of speciation (in sexual and asexual organisms) • Types of evolution (neutral, co-evolution); Types and levels of selection; r and k selection; molecular clocks; phylogeny and molecular distances	• Jacquelyn G. Black (2013) Microbiology: Principles and Explorations, 6th Edition, John Wiley & Sons, Inc., • Microbial Diversity: Form and Function in Prokaryotes, Published Online: 30 NOV 2007. DOI: 10.1002/9780470750490.ch1 • Copyright © 2005 by Blackwell Science Ltd • Carl R. Woese. The archaeal concept and the world it lives in: a retrospective. Photosynthesis Research 80: 361 – 372, 2004. Kluver Academic Publishers. • Ridley Mark (2004). Evolution. Blackwell Science Ltd.
1.02 TC	**Microbial diversity**	
	• The expanse of microbial diversity • Estimates of total number of species • Species Divergence and the measurement of microbial diversity. • Measures and indices of diversity.	• Species Divergence and the measurement of microbial diversity. Catherine Lozupone and Rob Knight. FEMS Microbiol. Rev. **32** (2008) 557 – 578 • Methods of studying soil microbial diversity. Jennifer Kirk *et al*, (2004). Journal of Microbiological Methods **58**, 169 – 188. • Keller M. and Zengler K. (2004) Tapping in to Microbial Diversity. Nature Reviews 2, 141-150. • Pace N. (1997) A Molecular View of Microbial Diversity and the Biosphere, Science, 276, 734-740. • Woese C. (1987), Bacterial Evolution. Microbiological Reviews, 221-271.

1.03 TC	**Taxonomy of Bacteria and Introduction to Bergey's Manuals**	
	• Introduction to Bacterial Taxonomy • Science of classification • The 5-Kingdom classification system • The 3-Domain classification system • Bergey's Manuals and the classification of prokaryotes. • Determinative Bacteriology (Phenetic Approach) • Systematic Bacteriology (Phylogenetic Approach • Polyphasic Approach	• Breed and Buchanan. Bergey's Manual of Determinative Bacteriology. 8th Edition, 1974. • Breed and Buchanan. Bergey's Manual of Determinative Bacteriology. 9th Edition, 1982. • Breed and Buchanan. Bergey's Manual of Systematic Bacteriology. 2nd Edition, (Volumes. 1 – 5) (2001 – 2003). • Sykes, G. and F. A. Skinner (Eds). Actinomycetales: Characteristics and Practical Importance. Society for Applied Bacteriology Symposium Series No. 2, Academic Press. 1973. • Jacquelyn G. Black (2013) Microbiology: Principles and Explorations, 6th Edition, John Wiley & Sons, Inc.,
1.04 TN	**Taxonomy of Fungi**	
	• The 6 Classes of Fungi. • The differentiating characters among different Classes of fungi. • The importance of morphological characters in fungal differentiation and classification.	• Barnett, H. L. and Hunter, B. B. 1960. Illustrated Genera of Imperfect Fungi. Burgess Publishing Co., Minnesota. • Lodder J. (1974). The Yeasts: A Taxonomic Study, North Holland Publishing Co. Amsterdam.
1.05 TN	**Exploration of Un-culturable bacteria**	
	• Concept of 'unculturable' bacterial diversity. • Strategies for culture of 'unculturable' bacteria. • Culture independent molecular methods for identifying unculturable bacteria. • Methods of extracting total bacterial DNA from a habitat and metagenome analysis.	1. Michael S. Rappe and Stephen J. Giovannoni (2003). The Uncultured Microbial Majority. *Annual Review of Microbiology*, **57**: 369 – 94. 2. Rakesh Sharma, Ravi Ranjan, Raj Kishor Kapardar and Amit Grover (2005). 'Unculturavble' bacterial diversity: An untapped resource. *Current Science*, **89 (1).** 3. Sonia R. Vartoukian, Richard M. Palmer and William G. Wade (2010). Strategies for culture of 'unculturable' bacteria. Minireview, FEMS Microbiol Lett **309**, 1 – 7. 4. James D. Oliver (2005). The Viable but Nonculturable State in Bacteria (2005). The Journal of Microbiology, **43**, Special Issue, 93 – 100.

1.06 TN	**Theories of Evolution**	
	• History and development of evolutionary theories. • Neo-Darwinism and its importance in prokaryote evolution. • Spontaneous mutation controversy, evolution of rates of mutation. • Types and levels of selection • Neutral evolution and molecular clocks, phylogeny and molecular distances • Co-evolution. • Molecular evolution • Speciation in sexual and asexual organisms, origin and stability of diversity, diversity of secondary metabolites.	1. Anders Gorm Pedersen, Molecular Evolution: Lecture Notes, February 2005. 2. Lindell Bromham and David Penny (2003). The Modern Molecular Clock. www.nature.com/reviews/genetics. MARCH 2003 | VOLUME 4, **Page. 216.** Nature Publishing Group. 3. Lively Curtis, M. (1996). Host-parasite coevolution and sex. Bioscience **46**, 2, 107. 4. Leo C. Vining (1992). Roles of secondary metabolites from microbes.Edited by Derek J. Chadwick, Julie. Whelm Copyright.
1.07 TN	**Gene sequencing**	
	• Objectives of gene sequencing • Challenges in gene sequencing • Vectors used in gene sequencing • Outline of gene sequencing procedures like • Maxam Gilbert's method, Sangers method, Pyrosequencing, Ion torrent • Isolation of DNA • Amplification of DNA by PCR • Gel electrophoresis • Automated Sequencer • BLAST analysis • DNA-DNA Hybridization methods • Strategies for whole genome sequencing • Whole Genome Shotgun Sequencing • Applications of gene sequencing (identification of organisms	1. Sandy Primrose, Richard Twyman, Bob Old (2001), Principles of Gene Manipulation 6th Edition, Blackwell Science Ltd. 2. Sambrook, J., Fritsch, E. F. And Maniatis, T. (1989) Molecular Cloning: A laboratory Manual, 2nd ed. Cold Spring harbour NY: Cold Spring Harbour Laboratory Press 3. Ausbel F. M. And Brent R. (1994) Current Protocols in Molecular Biology, John Wiley & Sons Inc, New York URL: ***National Center for Biotechnology Information*** *www.**ncbi**.nlm.nih.gov/* ***Ribosomal Database* Project - Release 10** *rdp.cme.msu.edu/* ***rdp.cme.msu.edu**/seqmatch/* **Building *phylogenetic trees*** **www.itu.dk/~sestoft/bsa/dinaws/**phylogeny**.html** **Reading a *Phylogenetic Tree* - Nature** *www.nature.com/.../reading-a-**phylogenetic-tree**-the-meaning-of-419.* ***PHYLIP* - Wikipedia, the free encyclopedia**

		en.wikipedia.org/wiki/PHYLIP ***MEGA* :: *Molecular Evolutionary Genetics Analysis*** *www.**mega**software.net/*

MB 502 - Quantitative Biology

Credit No.	Credit Title and Contents	References
1.08 TC	**Descriptive Statistics**	
	(No descriptive questions to be asked in examination; only appropriate problems should be asked in the examination.) • Measures of central tendency – Mean (arithmetic, geometric, harmonic), median , Percentile and mode; • Measures of dispersion – Mean deviation Standard deviation and Variance; • Measures of skewness; Measures of kurtosis; • Regression and correlation	1. Gupta S.P. Statistical methods, Sultanchand & Sons Publisher, New Delhi 2. Irfan Ali Khan and Atiya Khanum, Fundamentals of Biostatistics. 3rd Ed. Ukaaz, Publications, Hyderabad 3. Bernard Rosner Fundamentals of Biostatistics,5th Ed. Duxbury Thomson
1.09 TC	**Testing of Hypothesis - I**	
	• The concepts of null hypothesis, alternate hypothesis, • significance level, type I and type II errors, p-value, one tailed and two tailed tests • Distribution of sample means, standard error and confidence interval, Degrees of freedom • Equality of two population means, proportions: t-tests and z-test	1. Irfan Ali Khan and Atiya Khanum, Fundamentals of Biostatistics. 3rd Ed. Ukaaz, Publications, Hydrabad 2. Gupta S.P. Statistical methods, Sultan Chand & Sons Publisher, New Delhi 3. Norman T.J.Bailey Statistical methods in biology, 3rd Ed. Cambridge University Press
1.10 TC	**Testing of Hypothesis - II**	
	(No descriptive questions to be asked in examination; only appropriate problems should be asked in the examination.) χ^2 (chi square) test - test for goodness of fit, independence and homogeneity; Non-parametric tests (Run test, Sign test, Wilcoxon's signed rank test, Mann-Whitney test).	1. Irfan Ali Khan and Atiya Khanum, Fundamentals of Biostatistics. 3rd Ed. Ukaaz, Publications, Hydrabad 2. Gupta S.P. Statistical methods, Sultan Chand & Sons Publisher, New Delhi 3. Norman T.J.Bailey Statistical methods in biology, 3rd Ed. Cambridge University Press

1.11 TN	**Introductory Biostatistics**	
	• Importance of statistics in Biology, • Samples and Population, • Types of data, Random sampling methods and sampling errors, Scales and Variables, Accuracy and precision, • Collection and organization of data, tabulation, graphical representation (Histogram, frequency polygon and ogive curves, survival curves), diagrammatic representation (Simple bar diagram, percentage bar diagram, multiple bar diagram, sub-divided bar diagram and pie diagram). Kaplan Meier survival curve	1. Goon, Gupta and Dasgupta Fundamentals of statistics, World Press, Kolkata. 1. Gupta S.P. Statistical methods, Sultanchand & Sons Publisher, New Delhi. 2. Irfan Ali Khan and Atiya Khanum, Fundamentals of Biostatistics. 3rd Ed. Ukaaz, Publications, Hyderabad. 3. Lindgren B.W. Statistical Theory, Macmillan Publishing Co. Inc. 4. Wayne Daniel (2007) Biostatistics A foundation for Analysis in the health sciences, Edition 7, Wiley- India edition.
1.12 TN	**Probability and Probability Distributions**	
	(No descriptive questions to be asked in examination; only appropriate problems should be asked in the examination.) • Concept of experiment, event (mutually exclusive & non exclusive events, dependent & independent events); • Laws of probability (addition and multiplication); • Probability distribution – Normal (x-scale and z-scale), Binomial and Poisson distributions.	1. Irfan Ali Khan and Atiya Khanum, Fundamentals of Biostatistics. 3rd Ed. Ukaaz, Publications, Hydrabad 2. Gupta S.P. Statistical methods, Sultan Chand & Sons Publisher, New Delhi 3. Norman T.J.Bailey Statistical methods in biology, 3rd Ed. Cambridge University Press
1.13 TN	**Designing of Experiments**	
	Comparison of sample of 3 or more samples – F-test, ANOVA Survey design, Factorial design (Plackett Burman, DOE etc.) Designing Epidemiological studies: Basic measurements in epidemiology (Rates, ratios, proportions) for Mortality, Morbidity, Incidence and Prevalence, Risk estimations. Randomization, Bias removal (Blinding – single & double) Study designs for: Case control, cohort, concurrent, cross-sectional, retrospective/prospective, clinical/field trials, controlled and uncontrolled trials	1. Irfan Ali Khan and Atiya Khanum, Fundamentals of Biostatistics. 3rd Ed. Ukaaz, Publications, Hyderabad 2. Norman T. J. Bailey Statistical methods in biology, 3rd Ed. Cambridge University Press 3. Gupta S.P. Statistical methods, Sultan Chand & Sons Publisher, New Delhi 4. Montgomery D.C. Design and analysis of experiments, John Wiley & Sons 5. Bernard Rosner Fundamentals of Biostatistics,5th Ed. Duxbury Thomson Learning USA 6. Stephen Newman, Biostatistical methods in Epidemiology. Wiley Interscience Publication, USA 7. Aviva Petrie and Carolene Sabin, 2005, Medical Statistics at a glance, 2nd Edition, Blackwell

1.14 TN	Modeling in Biology	
	Concept, need, modeling the system of interest, Deterministic Vs Stochastic model *(Discuss following models with respect to variables, mathematical expression, solution of the expression, etc.)* Population models: Exponential, logistic and chemostat models. Models based on Hardy-Weinberg equation. Epidemiological models : Susceptible Infected Recovery (SIR) model and compartmental models	1. Haefner James W. (1996) Modeling Biological Systems : Principles and Applications, Kluwer Academic Publications 2. David Brown & Peter Rothery. Models in biology: mathematics, statistics, and computing John Wiley & Sons, USA

MB 503 – Cell Organization and Biochemistry

Credit No.	Credit Title and Contents	References
1.15 TC	**Biochemistry of Proteins and Nucleic acid**	
	Protein Chemistry: Structural features of amino acids, classification of amino acids, amino acids as buffers, Henderson Hasselbalch equation and its role in buffer formulation, peptide linkage, partial double bond nature of peptides, determination of primary structure of polypeptide (N-terminal, C-terminal determination, method of sequencing of peptides), MALDI-TOF and MS in protein sequencing, structural classification of proteins, primary, secondary, tertiary, quaternary structures of proteins, Nucleic acid chemistry: Structure of bases, nucleosides, nucleotides, phosphodiester linkages, 5' phosphate, 3'hydroxyl polarity of nucleic acids, tautomeric forms of bases and their implication in pairing of bases, structure of DNA (A, B and Z forms), Tm value Cot curves, structure of t-RNA, r-RNA, and m-RNA and other RNAs	1. Nelson D. L. and Cox M. M. (2002) *Lehninger's Principles of Biochemistry*, Mac Millan Worth Pub. Co. New Delhi 2. Segel Irvin H. (1997). *Biochemical Calculations*. 2nd Ed. John Wiley and Sons, New York. 3. Campbell M. K.(1999)Biochemistry. 3rd edition Harcourt Brace College Publishers 4. Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry*. 3rd Ed. Brooks/Cole, Publishing Company, California.

1.16 TC	**Ultrastructure and Organization of Eukaryotic Cell**	
	Structural organization of: Cytoskeleton, Endoplasmic Reticulum, Golgi apparatus, Protein trafficking among various cellular compartments; Events in cell cycle, Regulation of cell cycle, apoptosis. Localization of macromolecules using electron microscopy, Immunoelectron microscopy, and Confocal microscopy	1. Alberts Bruce (1985) *Molecular Biology of Cell*. Garland Pub 2. Metzler David E. (2001) *Biochemistry: The chemical Reactions of Living Cells*, Volume 1&2, Academic Press California. 3. Harvey Lodish, Arnold Berk, S. Lawrence Zipursky, Paul Matsudaira, David Baltimore, and James Darnell (2000) Molecular Cell Biology, 4th edition, W. H. Freeman & co., New York.
1.17 TC	**Development and Differentiation**	
	Introduction to Developmental Biology, Conserved nature of development, Concepts of commitment, determination and differentiation, Morphogen gradients in developmental regulation, Hox code, MPF, gastrulation and cellular movements involved in it, Organizer and its importance giving examples of invertebrates (*Drosophilla*) and vertebrate (*Xenopus*) model systems, pattern formation in body axis, antero-posterior and dorso-ventral polarity	a. Gibert Scott F. (2003). *Developmental Biology*. 7th Ed. Sinauer Associates Inc. Mass. USA. 2. Muller W.A. (1997) Developmental Biology, Springler Verlag, New York, Inc. 3. Wolpert Lewis (1998) *Principles of Development*. Oxford University Press Oxford
1.18 TN	**Communication And Coordination among microorganisms**	
	Life cycle of *Dyctiostellium discoidum*, Molecular mechanism of quorum sensing in slime moulds, Life cycle of myxobacteria, Molecular mechanism of quorum sensing in myxobacteria. Quorum sensing in Gram positive and Gram negative bacteria, Biofilms, their organization, signals involved in their formation and dispersal, applications of study on biofilms in pathogenic and non-pathogenic environments	1. Hamilton W. Allan, (1987) *Biofilms: Microbial Interactions and Metabolic activities*, in Ecology of Microbial Communities, (Eds. M. Fletcher, T. R. G. Gray and J. G. Jones) Cambridge University Press, Cambridge. 2. Petersm J. E. (1969) Isolation, cultivation and maintenance of *Myxobacteria*, Methods in Microbiology (Eds. Norris J. R. and W. Ribbons) Vol. 3B, Academic Press London, 185-210. 3. Toole 'O' George, H. B. Kaplan, R. Kolter,(2000) *Biofilm formation as microbial development* Annual Review of Microbiology, Vol. 54, 49-79 4. Melissa B. Miller and Bonnie L. Bassler (2001) *Quorum sensing in bacteria***.** Annu. Rev. Microbiol. Vol. 55, 165–99. 5. Christopher M. Waters and Bonnie L. Bassler (2005) *Quorum sensing:cell-to-cell communication in bacteria*. Annu. Rev. Cell Dev. Biol. Vol. 21, 319–46.

1.19 TN	**Bioorganic Chemistry**	
	a. Chemical reactivity: Concept and factors affecting reactivity (Inductive effect, Resonance / Mesomeric effect, Conjugation and Hyper-conjugation, Tautomerism, etc.) b. Bonding other than covalent – H-bonds, Van der Wall's interaction, charge transfer complexes, ionic bonding, Ion-dipole, Host-guest interactions c. Reactions of organic molecules: A brief overview of important reactions in organic chemistry e.g. Substitution, Addition, Elimination, Rearrangement, Oxidation, Reduction, etc. d. Bioorganic mechanism of enzyme catalyzed reactions: Acid – base, covalent catalysis and metal ion catalysis with examples of respective enzymes **e.** Stereochemistry: Three dimensional shape of molecules, conformation and configuration, structure and biological activity **f.** Concept of pH of weak acids and weak bases, Henderson-Hasselbalch equation, concept of buffer, strength of buffer, buffer value, important biological buffers	1. Clayden, Greeves, Warren and Wothers, *Organic Chemistry*, Oxford Press 2. Jerry March, *Advanced Organic Chemistry*, John Wiley 3. Voet Donald and Voet Judith G. (1995) *Biochemistry*, 2nd Ed.. John Wiley and sons, New York. 4. Conn Eric, Stumpf Paul K., Bruuening George, Doi Roy H., (1987) *Outlines of Biochemistry* 5th Ed , John Wiley and Sons, New Delhi.
1.20 TN	**Carbohydrate and lipid biochemistry**	
	a. Carbohydrate Chemistry: Mono, di, oligosaccharides and polysaccharides, with examples, asymmetric centre in sugars, D-series, L-series, dextro, leavo-rotatory, reducing and non-reducing sugars, sugar anomers, sugar epimers, sugar derivatives such as sugar alcohols, amino sugars, sugar acids, deoxy sugars, Methods of estimation of carbohydrates b. Lipid Chemistry: Classification of lipids according to chemical structure, fatty acids, saturated, unsaturated, branched, nomenclature system, structure and function of triglycerides, phospholipids, sphingolipids, terpenes, prostaglandins, waxes, and steroids, methods of estimation and characterization of lipids	1. Nelson D. L. and Cox M. M. (2002) *Lehninger's Principles of Biochemistry*, Mac Millan Worth Pub. Co. New Delhi 2. Segel Irvin H. (1997). *Biochemical Calculations*. 2nd Ed. John Wiley and Sons, New York. 3. Campbell M. K. (1999) Biochemistry. 3rd edition Harcourt Brace College Publishers 4. Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry*. 3rd Ed. Brooks/Cole, Publishing Company, California.

1.21 TN	Biochemical role of Micronutrients	
	a. Structure, function, and biochemical mechanism of following micronutrients in metabolism b. Water soluble vitamins and their coenzyme forms (Niacin, Riboflavin, Pantothenic acid, Thiamine, Pyridoxal, Vitamin B_{12}, Folic acid, Glutathione) c. Fat soluble vitamins (A, D, E, and K) d. Minerals as vitamins (Iron, Manganese, Magnesium, Cobalt, Molybdenum, Copper, Zinc, Nickel)	Nelson D. L. and Cox M. M. (2002) *Lehninger's Principles of Biochemistry*, Mac Millan Worth Pub. Co. New Delhi
1.22 TN	**Hormones and their function**	
	The chemical structure and functions of each hormone in connection with the gland responsible for its production: The thyroid a. The parathyroid b. The pancreas c. The adrenals d. The pituitary glands e. Sex hormones	1. Nelson D. L. and Cox M. M. (2002) *Lehninger's Principles of Biochemistry*, Mac Millan Worth Pub. Co. New Delhi 2. Physiological chemistry –Harper, 17ed, Lange medical

MB 511: Practical Course 1: Microbial Diversity & Systematics

1.23 PC	Isolation and identification of Eubacteria	
	• Isolation of the following types of bacteria from natural samples. Identification of the bacteria to at least the Genus level using the Bergey's Manuals: • Mesophilic bacteria • Actinomycetes • Thermophiles The identification key must be designed for each isolated and identified bacterium. Students are expected to isolate at least one Genus from each group.	1. Breed and Buchanan. Bergey's Manual of Determinative Bacteriology. 8th Edition, 1974. 2. Breed and Buchanan. Bergey's Manual of Determinative Bacteriology. 9th Edition, 1982. 3. Breed and Buchanan. Bergey's Manual of Systematic Bacteriology. 2nd Edition, (Volumes. 1 – 5) (2001 – 2003). 4. Sykes, G. and F. A. Skinner (Eds). Actinomycetales: Characteristics and Practical Importance. Society for Applied Bacteriology Symposium Series No. 2, Academic Press. 1973.

<table>
<tr><td>1.24 PC</td><td colspan="2">Isolation and identification of Fungi</td></tr>
<tr><td></td><td>Isolation of the following types of fungi from natural samples. Identification of the fungi.
• Molds (Saprophytic)
• Yeasts
The identification key must be designed for each isolated and identified fungus. Students are expected to isolate at least one Genus from Mold and Yeast each.</td><td>1. Barnett, H. L. and Hunter, B. B. 1960. Illustrated Genera of Imperfect Fungi. Burgess Publishing Co., Minnesota.
2. Lodder J. (1974). The Yeasts: A Taxonomic Study, North Holland Publishing Co. Amsterdam.</td></tr>
<tr><td>1.25 PC</td><td colspan="2">Isolation and identification of Cyanobacteria</td></tr>
<tr><td></td><td>Isolation and identification of any one type of cyanobacterium from a natural sample.

The identification key must be designed for each isolated and identified cyanobacterium. Students are expected to isolate at least one Genus of cyanobacteria.</td><td>Bergey's Manual of Systematic Bacteriology (2nd Edition)
Volume One: The Archaea and the Deeply Branching and Phototrophic Bacteria. Boone, David R.; Castenholz, Richard W. (Eds.). Originally published by Williams & Wilkins, 1984</td></tr>
<tr><td>1.26 PC</td><td colspan="2">Molecular Taxonomy</td></tr>
<tr><td></td><td>• Isolation, purification and checking purity of isolated chromosomal DNA of bacteria
• Demonstration of the following steps, if not possible to perform in your lab:
Cycle sequencing PCR
Purification of PCR product
Sequencing using automated machine
• Sequence matching by BLAST analysis.
• Drawing phylogenetic tree using related sequences (Using standard software like Phylip, Mega etc)</td><td>1. Sandy Primrose, Richard Twyman, Bob Old (2001), Principles of Gene Manipulation 6th Edition, Blackwell Science Ltd.
2. Sambrook, J., Fritsch, E. F. And Maniatis, T. (1989) Molecular Cloning: A laboratory Manual, 2nd ed. Cold Spring harbour NY: Cold Spring Harbour Laboratory Press
3. Ausbel F. M. And Brent R. (1994) Current Protocols in Molecular Biology, John Wiley & Sons Inc, New York
URL:
<u>National Center for Biotechnology Information</u>
www.ncbi.nlm.nih.gov/
<u>Ribosomal Database</u> Project - Release 10
rdp.cme.msu.edu/
rdp.cme.msu.edu/seqmatch/
<u>Building phylogenetic trees</u>
www.itu.dk/~sestoft/bsa/dinaws/phylogeny.html
<u>Reading a Phylogenetic Tree - Nature</u>
www.nature.com/.../reading-a-phylogenetic-tree-the-meaning-of-</td></tr>
</table>

		419. ***PHYLIP* - Wikipedia, the free encyclopedia** ***en.wikipedia.org/wiki/PHYLIP*** ***MEGA* :: *Molecular Evolutionary Genetics Analysis*** *www.**mega**software.net/*
1.27 PC	**Research Methodology - I**	

	Scientific communication
	The objective of this practical will be preparing a research paper based on sample data from the practical experiments conducted. The data generated through the experiments of the student should be used for this exercise.
	All the following aspects can be included in the final report and presentation:
	• Literature review (and choosing a suitable topic)
	• Experiment planning
	• Experimentation, with the use of contemporary methods and standard protocols
	• Representation of and calculations for data obtained
	• Interpretation of data with the use of statistical tools (if required)
	• Writing progress reports / synopsis / abstract of the work done (as applicable).
	• Writing a pedagogical (academic) article on a scientific theme (Review).
	• Oral presentation: Critically commenting on a manuscript (Research Paper / Article).
	• Preparation of display material (such as scientific posters)
	• Preparation of Visual Aids:
	  • Photomicrography, taking photographs of experimental results and using them in the reports
	  • Scanning pictures
	  • Making Power Point slide shows
		• Alley, M. 1996. The craft of scientific writing, 3rd edition. Prentice Hall, NJ. [and accompanying web site: http://filebox.vt.edu/eng/mech/writing/]
		• Day, R. 1998. How to write and publish a scientific paper, 5th edition. Orynx Press.
		• Day, R. 1995. Scientific English: A guide for scientists and other professionals, 2nd edition. Orynx Press.

MB 512: Practical Course II: Cell Biology and Biochemistry

1.28 PC	**Biochemistry-I**	
	1. Good laboratory practices: Laboratory safety, hazard from chemicals, handling of chemicals, disposal of chemicals and cultures, recording of scientific experiments. Standardization of laboratory procedures, calibration and validation instruments, preparing / designing SOP for the same, maintenance of instruments 2. Buffer: Determination of pKa of a monoprotic weak organic acid; Preparation of buffers using KH_2PO_4 and K_2HPO_4, acetic acid and sodium acetate, K_2HPO_4 and H_3PO_4	
1.29 PC	**Biochemistry-II**	
	1. Chromatography: Separation of sugar and amino acids by paper and thin layer chromatography 2. Colorimetry and spectrophotometry: Estimation of sugar and total carbohydrate, estimation of protein by Lowry, Bradford and UV Spectrophotometry	
1.30 PC	**Cell biology -I**	
	1. Studying the stages mitosis in growing tip of onion root cells 2. Demonstration of mounting of embryos (frog and fruit fly) at various developmental stages on permanent slides	
1.31 PC	**Cell Biology-II**	
	1. Isolation and characterization of bacterial pigment 2. Isolation and estimation of chromosomal DNA of bacteria	
1.32 PC	**Biostatistics**	
	1. Computer applications: Using data sheets, and sorting data with different parameters 2. Plotting graphs – bar charts, line graphs, pie charts, adding error bars 3. Statistical analysis of data – Students t test, ANOVA, Chi square test , F test using computer softwares (e.g. Microsoft Excel)	

Semester II

MB 601 - Instrumentation and Molecular Biophysics

Credit No.	Credit Title and Contents	References
2.01 TC	**Biomolecular Separation and Detection**	
	Chromatography- Partition Coefficient, Selectivity, Resolution, Column Efficiency, Van Deemter equation, Interpretation of chromatograms Principle, components of instrument, operation and application of : Gel filtration chromatography, Ion-exchange Chromatography, Affinity chromatography, Gas chromatography , High Performance Liquid Chromatography, Electrophoresis - AGE , NATIVE PAGE, SDS-PAGE , Isoelectric focusing. Ultra centrifugation, Differential centrifugation, Isopycnic and Rate zonal centrifugation,	• Clive Dennison (2002) *A guide to protein isolation*, Kluwer Academic Publishers • Pattabhi, V. and Gautham, N. (2002) *Biophysics.* Kluwer Academic Publishers, New York and Narosa Publishing House, Delhi. • David J Holme, Hazel Peck (1998) *Analytical Biochemistry* , 3rd ed ., Prentice Hall, Pearson Education Limited, Harlow England. • Rodney F. Boyer (2000*) Modern Experimental Biochemistr* 3d edition ., Benjamin Cummings. • Nölting, B. (2006) *Methods in modern biophysics.* Secor Edition. Springer, Germany.
2.02 TC	**Spectroscopies of Biomolecules**	
	Electromagnetic spectrum, Atomic orbitals, Molecular orbitals, Electronic, Rotational and Vibrational transitions in spectroscopy, Interpretation of spectra. • UV/Visible spectroscopy- Instrumentation, Molar Absorptivities, Beer and Lamberts Law, Bathochromic and hypsochromic shifts. • Fluorescence spectroscopy- Instrumentation, Quantum Yield, Quenching, FRET, Binding and Folding studies, • Infrared spectroscopy- Principle , Instrumentation, Absorption bands, FTIR and its advantages, • Circular Dichroism (CD) – Instrumentation, Circular polarization, Delta absorbance, Cotton Effect. • Mass spectroscopy- Principles of operation , Ionization, Ion fragmentation, Mass Analyzers, GC-MS, MALDI-TOF	• Wilson Keith and Walker John (2005) *Principles and Techniques of Biochemistry and Molecular Biology*, 6th Ed. Cambridge University Press, New York. • Pattabhi, V. and Gautham, N. (2002) *Biophysics.* Kluwer Academic Publishers, New York and Narosa Publishing House, Delhi. • Rolf Ekman, Jerzy Silberring, Ann Westman-Brinkmalm, Agnieszka Kraj (2009) *Mass spectrometry : instrumentation, interpretation, and applications*, John Wiley & Sons, Inc.,Canada. • Irwin H. Segel (1976) *Biochemical Calculations: How to Solv Mathematical Problems in General Biochemistry*, 2nd Editio John Wiley & Sons. • Nölting, B. (2006) *Methods in modern biophysics.* Secor Edition. Springer, Germany.

2.03 TC	**Biophysical Techniques**	
	• X-ray crystallography: Purification of proteins, Crystallization of proteins, Instrumentation, acquisition of the diffraction pattern, basic principles of x-ray diffraction, Crystal Structures (Bravais Lattices), Crystal planes and Miller Indices, Fourier Transform and Inverse Fourier, Direct Lattice and Reciprocal lattice, Ewald sphere, Electron density Maps, Phase determination, Phase Refinement, Validation. • NMR spectroscopy: Basic Principles of NMR, Chemical shift, Intensity, Line width, Relaxation parameters, Spin coupling, Nuclear Overhauser Effect Spectroscopy, Correlation Spectroscopy, Approach to structure determination by 2D-NMR	• Pattabhi, V. and Gautham, N. (2002) *Biophysics.* Kluwer Academic Publishers, New York and Narosa Publishing House, Delhi. • Cavanagh John *et.al.* (1995) *Proteins NMR Spectroscopy: Principles and Practice*, Academic Press. • Keeler, J. (2002) *Understanding NMR Spectroscopy.* John Wiley & Sons, England. • Drenth, J. (2007) *Principles of protein X-ray crystallography.* 3rd Ed. Springer, Germany. • Nölting, B. (2006) *Methods in modern biophysics.* Secon Edition. Springer,Germany. • Cotterill, R. M. J. (2002) *Biophysics: An Introduction.* Joh Wiley & Sons, England.
2.04 TN	**Protein Structure and Folding**	
	Physical and chemical properties of amino acids, non-covalent interactions, Conformational properties of proteins, Polypeptide chain geometry, Resonance forms of the peptide group, *cis/trans* isomers of peptide group, Ramachandran plot, Secondary, Super-secondary, Motif & Domain, Tertiary and Quaternary structures of proteins, (Myoglobin & hemoglobin)	• David J Holme, Hazel Peck (1998) *Analytical Biochemistry* , 3rd Ed., Prentice Hall, Pearson Education Limited, Harlow England. • Berg, J. M., Tymoczko, J. L. and Stryer, L. (2006) *Biochemistry.* 6th Edition. Freeman, New York. • Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry.* 3rd Ed. Brooks/ Cole, Publishing Company, California • Cotterill, R. M. J. (2002) *Biophysics: An Introduction.* Joh Wiley & Sons, England.
2.05 TN	**Tools of Bioinformatics**	
	General Introduction of Biological Databases, Introduction to Sequences, Sequence alignment, Local and global alignment, pair wise sequence alignment, Multiple sequence Alignment, Dynamic Programming, Homology Modelling, 3-D protein Model. Examples of related tools (FASTA, BLAST, BLAT), databases (GENBANK, PDB, OMIM) and software (RASMOL, Ligand Explorer).	• Mount, D. W. (2001) *Bioinformatics: sequence and genome analysis.* Cold Spring Harbor Laboratory Press, New York. • David M Webster (2000) *Protein Structure Prediction-Methods and Protocols,* Methods In Molecular Biology Vol 143 Humana Press. • Narayanan, P. (2000) Essentials of Biophysics. New Age International Publication, New Delhi.

2.06 TN	Synthesis and Characterization of Bio-Nanoparticles	
	Biogenic nanoparticles – Synthesis and applications. Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Role of plants in nanoparticle synthesis , Significance of the physical properties of nanoparticles Characterization of nanoparticles, Imaging techniques like TEM (Transmission Electron Microscope) , SEM (Scanning Electron Microscope), AFM (Atomic Force Microscopy), Dynamic Light Scattering (DLS), Scanning Probe Microscopy (SPM), EDAX analysis, Zeta analysis.	• Christof M. Niemeyer and Chad A. Mirkin (200 *Nanobiotechnology* , John Wiley & Sons. • Daniel L. Feldheim and Colby A. Foss, Jr. *(2002) Met nanoparticles synthesis and characterization and application* Marcel Dekker, Inc. • Mahendra Rai and Nelson Duran (2011) *Metal nanoparticles Microbiology*, Springer Verlag Berlin Heidelberg.

MB 602 – Virology

Credit No.	Credit Title and Contents	References
2.07 TC	**Structure and Replication of viruses**	
	Structure of Viruses • Enveloped and Non enveloped viruses • Capsid symmetries – Icosohedral, Polyhedral and Helical • Structural components of virus – Protein - Envelope proteins, Matrix proteins and Lipoproteins Genome – dsDNA, ssDNA, dsRNA, ssRNA (positive sense, negative sense and ambisense), linear, circular, segmented • Virus related structures – Viroids and Prions **Replication of viruses** • Mechanism of virus adsorption and entry into host cell • Genome replication • Post transcriptional processing • Translation of viral proteins • Protein nucleic acid interactions and genome packaging • Assembly, exit and maturation of progeny virions	1. Cann A.J, (2005), Principles of Molecular Virology, 4th Ed. Elsevier Academic Press. 2. Dimmock N. J., Easton A. J. and K. N. Leppard, (2007), Introduction to Modern Virology, 6th Ed. Blackwell Publishing. 3. Edward K. Wagner, Martinez J. Hewlett, (2004), *Basic Virology*, Blackwell Publishing 4. Flint S. J., V. R. Racaniello, L. W. Enquist, V. R. Rancaniello, A. M. Skalka, (2003), *Principles of Virology: Molecular Biology, Pathogenesis, and Control of Animal Viruses*, American Society Microbiology. 5. Haaheim L. R., J. R. Pattison and R. J. Whitley, (2002), *A Practical Guide toClinical Virology. 2nd Ed.* Edited by, John Wiley & Sons, Ltd. 6. Knipe David M., Peter M. Howley, Diane E. Griffin, Robert A. Lamb, Malcolm A. Martin, Bernard Roizman, Stephen E. Straus, (2007), *Field's Virology*, 5th Ed. Lippincott Williams

		& Wilkins 7. Luria S. E. et.al. (1978) *General virology*, 3rd Ed, New York. John Wiley and Sons. 8. Straus J. H. and Straus E.S. (1998) *Evolution of RNA Viruses* Ann. Rev. Microbiol. 42: 657 – 83
2.08 TC	**Cultivation and Detection methods for viruses**	
	Cultivation of viruses: • *In ovo*: using embryonated chicken eggs • *In vivo*: using experimental animals • *Ex vivo / In vitro:* using various cell cultures - primary and secondary cell lines, suspension cell cultures and monolayer cell culture • In plants and plant cell cultures **Diagnostic and detection methods for viruses:** • Sampling techniques and Processing of samples – Enrichment and concentration • Direct methods of detection – Light microscopy (inclusion bodies), Electron microscopy and Fluorescence microscopy • Immnuodiagnosis, Hemagglutination and Hemagglutination-inhibition tests, Complement fixation, Neutralization, Western blot, Radioactive Immuno Precipitation Assay (RIPA), Flow Cytometry and Immunohistochemistry • Nucleic acid based diagnosis: Nucleic acid hybridization, Polymerase Chain Reaction (PCR), Microarray and Nucleotide sequencing, LINE probe assay • Infectivity assay for animal and bacterial viruses - Plaque method, Pock counting, End point methods, LD50, ID50, EID50, TCID50 • Infectivity assays of plant viruses	1. Flint S. J., V. R. Racaniello, L. W. Enquist, V. R. Rancaniello, A. M. Skalka, (2003), *Principles of Virology: Molecular Biology*, *Pathogenesis, and Control of Animal Viruses*, American Society Microbiology. 2. Knipe David M., Peter M. Howley, Diane E. Griffin, Robert A. Lamb, Malcolm A. Martin, Bernard Roizman, Stephen E. Straus, (2007), *Field's Virology*, 5th Ed. Lippincott Williams & Wilkins 3. Mahy B. WJ. And Kangro H.O., (1996), Virology Methods Manual, Academic Press. 4. Shors T. (2011), Understanding Viruses, 2nd Ed., Jones & Bartlett Publishers LLC, Canada. 5. Stephenson J. R. and Warnes A., (1998), Diagnostic Virology Protocols: Methods in Molecular Medicine, Humana Press. 6. Wiedbrauk D. L. and Farkas D.H., (1995) Molecular Methods For Virus Detectin, Academic Press.

2.09 TC	**Nomenclature & Classification systems of viruses**	
	ICTV Nomenclature of viruses (Based on 9th Report – version 2012) • International Committee on Taxonomy of Viruses (ICTV) • ICTV Principles of Nomenclature • ICTV Rules of Classification and Nomenclature **ICTV Classification** of viruses (Based on 9th Report – version 2012) • Progression of ICTV classification system over a time period • Current status of ICTV virus classification • Criteria to differentiate virus orders, families, genera and species Classification of viruses based on: • Type of host (e.g. Plant, Animal, Bacteria) • Type of disease (e.g. Hepatitis A, B, C, D, E) • Type of transmission vector (e.g. , Fungi, Insects, Animal – murine, primate) Baltimore classification of animal viruses	1. Baltimore D. (1971), Expression of Animal Virus Genomes, Microbiology and molecular Bioology Reviews, 35(3), 235 – 241. 2. Cann A.J, (2005), Principles of Molecular Virology, 4th Ed. Elsevier Academic Press. 3. Cornelia Buchon-Osmond (2003), The Universal Virus Database ICTV db Computing in science and Engineering, May/June, pp 2-11. 4. Fenner F (1976) The Classification and Nomenclature of Viruses Summary of Results of Meetings of the International Committee on Taxonomy of Viruses in Madrid, September 1975, Journal of General Virology, 31, 463-470. 5. http://ictvonline.org/codeOfVirusClassification_2012.asp 6. Luria S. E. et.al. (1978) *General virology*, 3rd Ed, New York. John Wiley and Sons.
2.10 TN	**Bacteriophages**	
	Bacteriophage ecology Morphology, Genome organization and Life cycles • T (odd and even phages) • Lambda phage • M13 phage • Phi X 174 phage • MS2 phage Bacteriophage therapy for control of bacterial poultry diseases	1. Abedon S. T. (2008) Advances in Molecular and Cellular Microbiology Series, Bacteriophage Ecology: Population Growth, Evolution and Impact of Bacterial Viruses, Cambridge University Press. 2. Birge E. A. (2006) Bacterial and Bacteriophage Genetics, 5th Ed., Springer 3. Calendar R. and Abedon S. T. (2006), The Bacteriophages, 2nd Ed. Oxford University Press. 4. Douglas John, (1975), *Bacteriophages*, Chapman and Hall, London 5. Guttman Burton S. and Elizabeth M. Kutter, (2002), *Bacteriophage Genetics*, Uldis N. Streips and Ronald E. Yasbin, Editors, Modern Microbial Genetics, 2nd Ed., Wiley-Liss Inc.

		6. Hendrix R. W., (2002), *Bacteriophage λ and its relative*, Uldis N. Streips and Ronald E. Yasbin, Editors, Modern Microbial Genetics, 2nd Ed., Wiley-Liss Inc. 7. Weinbauer M. G. (2004) Ecology of prokaryotic viruses, FEMS Microbiology Reviews 28, 127 – 181.
2.11 TN	**Viral Therapeutics**	

	Vaccines
	Conventional vaccines: Killed and attenuated
	
	Modern vaccines: Concepts and examples (DNA vaccines, Recombinant DNA/protein vaccines, Subunits vaccines, Peptide vaccines, Anti-idiotype vaccines, Edible vaccines,
	
	Vaccine formulations and delivery: Adjuvants, immunomodulators, cytokines)
	
	Antivirals:
	• Designing and screening
	• Mechanism of action (e.g. Nucleoside analogues, Nucleotide analogues, Antisense, Topical immune modulator, neuraminidase inhibitors, Ion channel function inhibitors of M2 proteins, Pyrimidines)
	
	• Antiretrovirls
	  • Mechanism of action
	  • Mechanism of resistance
	
	Modern approaches of virus control
	• Small interfering RNA (siRNA)
	• Ribozymes
		1. Clercq E. (2004) Antivirals and antiviral strategies, Nature Reviews, 2, 704 – 720.
		2. Clerq E. (2011) A 40- year journey in search of selective antiviral chemotherapy, Annual Review of Pharmacology and Toxicology, 51, 1 - 24.
		3. Colmon M. P. (2009) New New antivirals and drug resistance, Annual Review of Biochemistry, 78, 95 – 118.
		4. Flint S. J., V. R. Racaniello, L. W. Enquist, V. R. Rancaniello, A. M. Skalka, (2003), Principles of Virology: Molecular Biology, Pathogenesis, and Control of Animal Viruses, American Society Microbiology.
		5. Idrees S. and Ashfaq U. A. (2013) RNAi: Antiviral therapy against dengue virus, Asian Pacific Journal of Tropical Biomedicine, 3(3), 232 – 236.
		6. Jarczak D., Korf M., Beger C., Manns M. P. and Kruger M. (2005) Hairpin ribozymes in combination with siRNAs against highly conserved hepatitis C virus sequence inhibit RNA replication and protein translation from hepatitis C virus subgenomic replicons, FEBS Journal, 272, 5910 – 5922.
		7. Knipe David M., Peter M. Howley, Diane E. Griffin, Robert A. Lamb, Malcolm A. Martin, Bernard Roizman, Stephen E. Straus, (2007), Field's Virology, 5th Ed. Lippincott Williams & Wilkins.
		8. Tyring S. K. (2005), Antiviral Agents, Vaccines, and Immunotherapies, Marcel Dekker/CRC Press.

2.12 TN	Animal Viral Diseases	
	Emerging viruses, Principles of viral disease control, elimination and eradication, (with examples of small pox, polio and rinderpest) Human viruses (Antigenic characteristics, pathophysiology and epidemiology) • Herpes viruses • HIV • Simian virus 40 Bovine viruses (Antigenic characteristics, pathophysiology and epidemiology) • Foot-and-mouth disease virus • Prion diseases of animals (Mad cow disease, scrapie disease) Avian viruses (Antigenic characteristics, pathophysiology and epidemiology) • Newcastle disease virus • Marek's disease virus Oncogenic viruses • Virus induced cell transformation and oncogenesis • Mechanism of cell transformation by RNA viruses and by DNA tumor viruses • Retrovirus mediated oncogenesis	1. Aylward R. B. and Jennifer Linkins (2005) Polio eradication: mobilizing and managing the human resources, 83(4), 268 – 273. 2. Barrett S. (2004) Eradication versus control: the economics of global infectious disease policies. Bulletin of the World Health Organization, 82 (9), 683 – 688. 3. Bart K. J., Foulds J. and P. Patriarca (1996) Global eradication of poliomyelitis: benefit – cost analysis, Bulletin of the World Health Organization, 74(1), 35 – 45. 4. Cann A.J, (2005), Principles of Molecular Virology, 4th Ed. Elsevier Academic Press. 5. Carter J. and Saunders V. (2007) Virology: Principles and Applications, John Wiley & Sons Ltd. 6. Dimmock N. J., Easton A. J. and K. N. Leppard, (2007), Introduction to Modern Virology, 6th Ed. Blackwell Publishing. 7. Dowdle W. R. (1998) The Principles of Disease Elimination and Eradication. Bulletin of the World Health Organization, 76(2), 22 – 25. 8. Duesberg P. H. (1987) Retroviruses as carcinogenes and pathogens: Expectations and reality, Cancer Research, 47, 1199 – 1220. 9. Kayser F. H., Bienz K. A., Eckert J. and Zinkernagel R. M. (2004), Medical Microbiology, Thieme. 10. Knipe David M., Peter M. Howley, Diane E. Griffin, Robert A. Lamb, Malcolm A. Martin, Bernard Roizman, Stephen E. Straus, (2007), *Field's Virology*, 5th Ed. Lippincott Williams & Wilkins 11. Mahy B. WJ. And Kangro H.O., (1996), Virology Methods Manual, Academic Press. 12. Murphy F. A., Gibbs E.P.J., Horzinek M.C. and Studdert M. J. (1999) Veterinary Virology, 3rd Ed. Academic Press. 13. Saha A., Kaul R., Murakami M. and Robertson E. S. (2010) Tumor viruses and cancer biology: Modulating signal

		pathaways for theraputic intervantion, Cancer Biology and Therapy, 10(10), 1 – 18. 14. Strauss J. H. and Strauss E. G. (2002), Viruses and Human Disease, Academic Press. 15. World Health Organization (2003) Global Polio Eradication Initiative: Strategic plan 2004 – 2008. 16. Zuckerman A. J., Banatvala J. E., Pattison J. R., Griffiths P.D. and B. D. Schoub, (2004), Principles and Practice of Clinical Virology, 5th Ed., John Wiley & Sons Ltd.
2.13 TN	**Plant Viral Diseases**	
	Effects of viruses on plants • Appearance of infected plants • Histological • Physiological and cytological changes in infected plants Behavior of viruses in plants • Early stages of infection • Biochemistry of virus replication • Cellular sites of virus replication and assembly • Release and translocation of virus particles in tissues Methods for detection of plant viruses • In seeds, seed stocks and diseased plants • Indicator plants • Antigen based methods • Histopathological methods Transmission of plant viruses • Through vectors - insects, nematodes and fungi • Without vectors - contact, seed and pollens Prevention of crop losses due to virus infection • Virus free planting material • Vector control • Disease forecasting	1. Agrios G (2005) Plant Pathology, 5th Ed., Elsevier Academic Press.Hull R (2002) Matthew's Plant Virology, 4th Ed., Academic Press. 2. Gibbs Adrian & Bryan Harrison ( ) Plant Virology -The Principles. Edward Arnold Press. 3. Hull R (2009) Comparative Plant Virology, 2nd Ed., Elsevier Academic Press. 4. Khan J. A. and J. Dijkestra (2002) Plant Viruses as Molecular Pathogens, Food Products Press. 5. Knipe David M., Peter M. Howley, Diane E. Griffin, Robert A. Lamb, Malcolm A. Martin, Bernard Roizman, Stephen E. Straus, (2007), Field's Virology, 5th Ed. Lippincott Williams & Wilkins 6. Prusiner S. B. (1995) The Prion Diseases, Scientific American (1):48-57 7. Reisner D. & Gross H.J. (1985) Viroids Ann. Rev. Biochem.54:531-64 8. Sherkar A. H. & Marion P.L. (1991) Hepo DNA viruses and Hepatocellular Carcinomas. Ann. Rev. Microbiol.45:475-508 9. Stephens B. and Compons R. W. (1998) Assembly of animal viruses at the cellularmembrane Ann. Rev. Microbiol.42:489-519

MB 603 – Microbial Metabolism

Credit No.	Credit Title and Contents	References
2.14 TC	**Enzyme Kinetics**	
	Purifications of enzyme, purification chart, kinetics of single substrate enzyme catalyzed reaction. Kinetics of reversible inhibitions enzyme catalyzed reactions, King Altman approach to derive – two substrate enzyme catalyzed reactions, types of two substrate enzyme catalyzed reactions, concept of allosterism, positive and negative co-operativity, models of allosteric enzymes (Monod, Wyamann and Changuax model, Koshland, Nemethy and Filmer model), kinetics of allosteric enzyme, Hill plot, examples of allosteric enzymes and their significance in allosteric regulation	1. Nelson D. L. and Cox M. M. (2005) *Lehninger's Principles of Biochemistry*, Fourth edition, W. H. Freeman & Co. New York. 2. Palmer Trevor (2001) *Enzymes: Biochemistry, Biotechnology and Clinical chemistry*, Horwood Pub. Co. Chinchester, England. 3. Segel Irvin H. (1997) *Biochemical Calculations* 2nd Ed., John Wiley and Sons, New York
2.15 TC	**Bioenergetics**	
	Laws of thermodynamics, entropy, enthalpy, free energy, free energy and equilibrium constant, Gibbs free energy equation, determination of free energy of hydrolytic and biological oxidation reduction reactions, under standard and non-standard conditions, high energy compounds, coupled reactions, determination of feasibility of reactions, Atkinson's energy charge, phosphorylation potential and its significance	1. Nelson D. L. and Cox M. M. (2005) *Lehninger's Principles of Biochemistry*, Fourth edition, W. H. Freeman & Co. New York. 2. Segel Irvin H. (1997) *Biochemical Calculations* 2nd Ed., John Wiley and Sons, New York 3. Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry.* 3rd Ed. Brooks/Cole, Publishing Company, California.
2.16 TC	**Aerobic and anaerobic respiration**	
	Structure of mitochondria, components and organization of mitochondrial electron transport chain, structure and function of ATPase, generation and maintenance of proton motive force, oxidative phosphorylation, inhibitors and un-couplers of electron transport chain and oxidative phosphorylation. Concept of anaerobic respiration, components of electron transfer system and energy generation of bacteria where nitrate, sulfate and carbonate acts as terminal electron acceptors	1. Moat Albert G. and Foster John W. (1988) *Microbial Physiology* 2nd Ed. John Wileyand Sons New York. 2. Nelson D. L. and Cox M. M. (2005) *Lehninger's Principles of Biochemistry*, Fourth edition, W. H. Freeman & Co. New York. 3. Michael T. Madigan, John M. Martinko, David A. Stahl, David P. Clark (2012) *Brock Biology of Microorganisms*, Thirteenth edition, Benjamin Cummings, San Francisco.

2.17 TN	**Membrane Transport**	
	The composition and architecture of membranes, Membrane dynamics, Solute transport across membranes: Passive diffusion, facilitated transport, primary and secondary active transport using P , V and F type ATPases, Ionophores, Ion mediated transport, transport of ions across membranes (ion pumps), ligand and voltage gated ion channels, liposomes and model membranes	1. Nelson D. L. and Cox M. M. (2005) *Lehninger's Principles of Biochemistry*, Fourth edition, W. H. Freeman & Co. New York. 2. Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry.* 3rd Ed. Brooks/Cole, Publishing Company, California. 3. Berg Jeremy, Tymoczko John, Stryer Lubert (2001) *Biochemistry* 4th Ed, W. H. Freeman, New York.
2.18 TN	**Nitrogen metabolism**	
	Biochemistry of biological nitrogen fixation, properties of nitrogenase and its regulation, ammonia assimilation with respect to glutamine synthetase, glutamate dehydrogenase, glutamate synthetase, their properties and regulation, Biosynthesis of five families of amino acids and histidine, Biosynthesis of purine and pyrimidine bases	1. White David (2000) *Physiology and Biochemistry of Prokaryotes.* 2nd Ed. Oxford University Press, New York. 2. Mandelstam Joel and McQuillen Kenneth (1976) *Biochemistry of Bacterial Growth*, Blackwell Scientific Publication London. 3. Nelson D. L. and Cox M. M. (2005) *Lehninger's Principles of Biochemistry*, Fourth edition, W. H. Freeman & Co. New York. 4. Moat Albert G. and Foster John W. (1988) *Microbial Physiology* 2nd Ed. John Wiley and Sons New York. 5.
2.19 TN	**Photosynthesis**	
	Structure of chloroplast, energy consideration in photosynthesis, light and dark reaction, electron carriers in photosynthesis, Organization of photosystem I and II, cyclic and non-cyclic flow of electrons, Z scheme, Hill reaction, photolysis of water, C_3, C_4 CAM plants, Photorespiration, Regulation of photosynthesis, Bacterial photosynthesis: scope, electron carriers, Photosynthetic reaction center, cyclic flow of electrons, bacterial photophosphorylation in various groups of phototrophic bacteria, electron donors other than water in anoxygenic photosynthetic bacteria	1. Nelson D. L. and Cox M. M. (2005) *Lehninger's Principles of Biochemistry*, Fourth edition, W. H. Freeman & Co. New York 2. Hall D. D. and Rao K. K. (1996) *Photosynthesis* 5th Ed., Cambridge University Press 3. Michael T. Madigan, John M. Martinko, David A. Stahl, David P. Clark (2012) *Brock Biology of Microorganisms*, Thirteenth edition, Benjamin Cummings, San Francisco.

2.20 TN	**Biosynthesis of carbohydrates in plants and bacteria**	
	Calvin cycle and its regulation, Transport of solute across chloroplast membrane, Synthesis of starch and sucrose, Photorespiration, C_4 and CAM pathways, synthesis of cellulose and peptidoglycan, integration of carbohydrate metabolism in plant cell.	1. Cox M. M., Nelson D. L., (2008) Lehninger Principles of Biochemistry, Fifth edition, W. H. Frreman and Company New York 2. Berg Jeremy, Tymoczko John, Stryer Lubert (2001) *Biochemistry* 4th Ed, W. H. Freeman, New York. 3. Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry.* 3rd Ed. Brooks/Cole, Publishing Company, California
2.21 TN	**Lipid biosynthesis**	
	Synthesis of storage lipids: Fatty acids and triacylglycerols, Synthesis of membrane lipids: Glycerophospholipids, sphingolipids, sterols, Lipids as signal molecules such as phosphatidyl inositol, eicosanoids, Vitamins, A, D, K, and E, Dolichols.	1. Cox M. M., Nelson D. L., (2008) Lehninger Principles of Biochemistry, Fifth edition, W. H. Frreman and Company New York 2. Berg Jeremy, Tymoczko John, Stryer Lubert (2001) *Biochemistry* 4th Ed, W. H. Freeman, New York. 3. Garrett, R. H. and Grisham, C. M. (2004) *Biochemistry.* 3rd Ed. Brooks/Cole, Publishing Company, California

MB 611: Practical Course 1: Biophysics & Virology

2.22 PC	**Biophysical Instrumentation - I**	
	1. Calibration of analytical instruments – Colorimeter and Spectrophotometer by estimation of biomolecules and statistical analysis of data generated. 2. Determination of molar extinction coefficient of biological molecule. 3. To determine the ion-exchange capacity and nature of given resin using anion exchange chromatography.	
2.23 PC	**Biophysical Instrumentation - II**	
	1. Biological synthesis of nanoparticles (actinomycetes /fungi /yeast) and their characterization by UV-Vis spectroscopy. 2. Interpretation of Ramchandran Plot and study of conformations of protein molecule using Molecular Graphics Visualization Tool.	

2.24 PC	**Virology (Plant Viruses)**	
	1. Preparation of plantlets from seeds of indicator plant, leaf infection and infectivity assay for plant mosaic viruses 2. Study of plant virus diseases: Collecting data and samples (preparation of herbaria) 3. Chloroplast agglutination test	
2.25 PC	**Virology (Animal & Bacterial Viruses)**	
	1. Egg inoculation technique for virus cultivation by various routes - embryo, yolk sac, allantoic fluid, amniotic cavity, chorioallontoic membrane. 2. Animal virus titration by Hemagglutination test 3. Confocal Microscopy demonstration / Analysis of confocal images 4. Qualitative and quantitative detection of bacteriophage 5. One step growth curve of bacteriophage	
2.26 PC	**Research Methodology - II**	
	Dissertation Techniques 1. Literature review (and choosing a suitable topic) 2. Experiment planning 3. Experimentation, with the use of contemporary methods and standard protocols 4. Representation of and calculations for data obtained 5. Interpretation of data with the use of statistical tools (if required) 6. Writing monthly progress reports / synopsis / interim reports 7. Writing a Masters' thesis 8. Presenting the thesis in an 'Open Defense'	

MB 612: Practical Course 2: Enzymology & Microbial Metabolism

2.27 PC	**Purification & Assay of Enzymes**	
	1. Purification of enzyme from natural sources like animal, plant, bacterial/fungal by ammonium sulfate precipitation, organic solvent precipitation, gel filtration, etc. 2. Establishment of enzyme purification chart 3. Determination of Km and Vm values of any hydrolytic enzyme 4. Protein electrophoresis by PAGE and SDS PAGE	
2.28 PC	**Isolation and Characterization of Anaerobic Bacteria**	
	1. Different methods of isolation and cultivation of anaerobic bacteria 2. Isolation and purification of sulfate reducing bacteria 3. Isolation and purification of anaerobic respiratory clostridia	
2.29 PC	**Microbial Metabolism-I**	
	1. Isolation and characterization of (as nitrogen fixers) *Azospirillum* and detection of IAA by *Azospirillum* 2. Detection of siderophore production by *Azospirillum* and *Pseudomonas*	
2.30 PC	**Microbial Metabolism-II**	
	1. Isolation and characterization of phosphate solublizing bacteria 2. Isolation and characterization of chitin, cellulose and pesticide degrading bacteria	
2.31 PC	**Extraction, detection and characterization of aflatoxins**	
	1. Isolation of Aflatoxin producing organism **2.** Detection of Aflatoxin in food / culture	