

Manonmaniam Sundaranar University

Abishekapatti – 627 012

Ph. D. PROGRAM IN BOTANY

(For all affiliated colleges/Research centres and University Department)

Course Structure and Syllabus as per the Choice Based Credit System (CBCS)

(Curriculum Effective From July 2017 Onwards)

Course Structure for Ph. D. Program in Botany – 2017 onwards

S. No.	Name of the course	Hrs/week	Credits
CORE PAPERS			
1	Research and Teaching Methodology	4	4
2	Advances in Plant Science	4	4
ELECTIVE PAPERS			
3	Plant Conservation Biotechnology	4	4
4	Developmental Botany & Plant Biotechnology	4	4
5	Phytochemistry and Pharmacognosy	4	4
6	Bio fertilizers and Plant Responses	4	4
7	Soil Fertility and Plant Nutrition	4	4
8	Ecology, Biodiversity and Sustainability	4	4
9	Taxonomy of Angiosperms	4	4
10	Plant Anatomy and Reproductive Biology	4	4
11	Algal Technology	4	4
12	Bryophyte Systematics and Evolution	4	4
13	Ethnomedicine	4	4
14	Marine Botany	4	4
15	Vascular Cryptogams	4	4
MINI PROJECT			
	Mini Project	4	4

Candidates with PG qualification should earn a total of 16 credits

Candidates with M.Phil. qualification should earn a total of 8 credits

RESEARCH AND TEACHING METHODOLOGY

L	C
60	4

Objectives

- To understand the principles and operation of basic and advanced instruments required for doctoral research
- To analyse the scientific findings and data by applying certain statistical methods and software
- To learn the methods of teaching and carrying out scientific research, documentation and communication

Unit I Microscopic and Analytical techniques (15 hrs)

Microscopy-principles and applications. Properties of electromagnetic radiation- Light, Phase contrast and Fluorescence microscopy. Electron Microscopy-Principles and applications of TEM and SEM- Preparation of materials for Electron Microscope.Spectroscopic techniques- UV and Visible, Fluorescence, IR, NMR, AAS, AES and AFM. Electrochemical techniques- Radioisotope techniques-radioactivity, atomic stability and radiation-radiation decay. Detection and measurement of radioactivity and applications of Geiger-Müller and Scintillation Counter. Labelling of biological molecules and autoradiography.

Unit II Separation techniques (8 hrs)

Chromatography- Principles and applications- GC, GLC, HPLC, MS.Electrophoretic techniques- Principles and construction of horizontal and vertical electrophoresis-Buffers and electrolytic separation- detection by staining and estimation of electrophorogramsgel documentation. Molecular techniques: PCR based-RFLP, RAPD, AFLP, SSR, blotting techniques.

Unit III Statistical Methods (10 hrs)

Population and sampling, data collection, analysis and graphical representation. Measures of Central Tendency, Measures of Dispersion-Standard Deviation, Correlation and Regression analysis, Probability -normal and binomial distribution. Statistical testing: F-test, t-test and chi-square test. Experimental design, ANOVA one way and two way analysis, statistical software- MS Excel and SPSS.

Unit IV Research Methods (12 hrs)

Research- Meaning - Role of a researcher – Hypothesis - Methods-Approaches Objectives. Literature and Reference collection. Role of libraries in research, virtual libraries, Internet-Worldwide web-searching and browsing tools- e-journals and e-books. Impact factor, H- index, citation. Manuscript preparation- Citation and Proof correction, Thesis/Dissertation components - Introduction, Review, Materials and methods, Results -tables, figures, footnote, Discussion, Summary and Conclusion. Role of Supervisors/Guides in research.

Unit – V Teaching methods (15 hrs)

Teaching – Objectives of teaching, phases of Teaching – Teaching methods: lecture method, discussion method, discovery learning, Inquiry, Problem solving method, project method. Seminar- Integrating ICT in teaching: Individualised instruction, ways for effective presentation with power points, documentation - Evaluation; formative, summative & continuous and comprehensive Evaluation. Later Adolescent Psychology: meaning, physical, cognitive, emotional, Social and moral Development –Teaching later adolescents.

Reference Books:

1. Bryan C Williams and Keith Wilson 1983, A biologist's guide to practical techniques of Practical Biochemistry Second edition. Edward Arnold Publications.
2. David Plummer, 1988. An Introduction to Practical Biochemistry, Tata McGraw Hill Publishing Company, New Delhi.
3. George Casella and Roger L. Berger, 2003. Statistical Inference II Ed. Duxbury Advanced Series, Thomson Press.
4. Jayaraman, J,1985. Laboratory Manual in Biochemistry, Wiley Eastern Ltd.
5. Johansen, M., 1940. Plant Microtechnique, McGraw Hill Publishing Company, New Delhi.
6. Keith Wilson and John Walker., 2000. Practical biochemistry V Edition Cambridge Universities Press, London.
7. Stock, R and Rice, C.B. F., 1980. Chromatographic methods, Chapman and Hall Ltd. London.
8. Steel and Torrie, 1986. Principles and Procedures of Statistics with special reference to Biological Sciences.
9. Kothari, C.R., 2004. Research Methodology Methods and Techniques, New Age International
10. Isaac, S., Michael, W., 1971. Handbook in research and evaluation, (2nd ed.), San Diego, USA
11. Gomez, K.A., Gomez, A.A., 1984. Statistical procedures for agricultural research, John Wiley & Sons.
12. Townend, J., 2012. Practical statistics for environmental and biological scientists, John Wiley & Sons.
13. Sampathkumar, K, Panneerselvam, A. & Santhanam, S. 1984. Introduction to educational technology 2nd revised ed. Sterling Publishers, New Delhi.
14. Sharma, S. R. 2003. Effective classroom teaching modern methods, tools and techniques. Mangal Deep publishers, Jaipur.
15. Vedanayagam, E. G. 1989. Teaching technology for college Teachers, Sterling publishers, New York.

ADVANCES IN PLANT SCIENCE

L	C
60	4

OBJECTIVES

- To comprehend the important aspects of biodiversity and conservation methods
- To make the scholar abreast in advanced areas of plant science and the recent developments
- To equip the scholar to learn the theoretical and application concepts on economic and medicinal importance of plants

Unit 1- Climate change and plant diversity (12 hrs)

Biodiversity – Alpha, Beta, Gamma; Species, genetic and ecosystems diversity. Centres of origins of crops – Vavilov’s Theory, Megabiodiversity, centres of origin of genetic diversity, Plant Genetic Resources (IBPGR/ NBPGR). Endangered plants – IUCN categories, Red Data Books, *In Situ* and *Ex situ* conservation strategies. Components of the atmosphere, greenhouse gases & green house effect, global warming and climate change, sea level rise, increased CO₂ levels, impacts on plants. Carbon sequestration, carbon credits and economy and energy policy. Climate Change adaptation and mitigation strategies (UNEP/ FAO/ IPCC / GBIF / CBD).

Unit -2 Plant Physiology (12 hrs)

Photosynthesis recent concepts in Photosystems I & II, ATP complex. Chloroplast DNA. Water transport and utilization. Resource mobilization and allocation. Advances in auxin and cytokinin molecular synthesis and function. Biochemistry of plant animal interaction.

Unit – 3. Plant Energy (12 hrs)

The concept of energy richness in plants – lignocelluloses, sugars and terpenoids. Plants that produce fuel, wood, waxes, alcohol and hydrocarbons. Products include biodegradable plastics, industrial enzymes, industrial oils, biofuels, fibers, papers, agents for bioremediation, phytoremediation.

Unit – 4 Molecular biology (12 hrs)

Cloning vectors and Transgenics. Genetic improvement of medicinal plants through Biotechnology and Genetic engineering. Molecular diversity analysis using various types of markers. Applications of molecular techniques in herbal research. Applications of *in-vitro* culture methods in drug production. Growing and harvesting genetically engineered crops to produce compounds of industrial importance.

Unit – 5 Advances in Plant Medicines (12 hrs)

Plants as bioreactors, molecular pharming - production of pharmaceutically valuable compounds from plants. Plant made pharmaceuticals (PMP). Plantibodies Edible Vaccines / Plantigens,

Interferon's, Blood clotting factors, Anticoagulant, Hormones, Enzymes, Secondary metabolites, other proteins. IPR and medicinal plants.

References

- 1) Melchias, G. 2001. Biodiversity and Conservation. Science Publishers, NH USA
- 2) Krishnamurthy K.V. 2004. Advanced Textbook on Biodiversity: Principles and Practice. Oxford & IBH, New Delhi.
- 3) The World Conservation Strategy. IUCN, Switzerland.
- 4) Heywood, VH (Ed.). 1995. Global Biodiversity Assessment Report .UNEP.
- 5) Bidwell. R. G. S. 1979 Plant Physiology. Macmillon Delhi.
- 6) Lea, P. J. and R. C. Leegood. 1993. Plant Biochemistry and Molecular Biology, JohnWiley & Sons. New York.
- 7) Hans-walter heldt. 1997. Plant biochemistry and molecular biology. Oxford university press, New York. USA.
- 8) Jogdand. S.N.1997. Environmental Biotechnology – Industrial Pollution Management. Himalaya Publishing House.
- 9) Watson, J.D. and W.A. Benjamin. 2004. 3rd Edition. Molecular Biology of the Genes. Benjamin Cummings.
- 10) Freifelder, D. 1983. Molecular Biology. 2nd Ed. Narosa publishing house.
- 11) Lodish, H., Berk, A., Zipursky, S.L., Matsudaira, P., Baltimore, D. and Darnell, J. 2000. Molecular Cell Biology, W.H. Freeman and Co., New York, USA.
- 12) Wolfer, S.L. 1993 Molecular and Cellular Biology, Wadsworth Publishing, USA.
- 13) Revised guidelines for research in Transgenic plants (August 1998), Department of Biotechnology, Ministry of Science & Technology, Government of India, New Delhi.

PLANT CONSERVATION BIOTECHNOLOGY

L	C
60	4

OBJECTIVES

- To study the essentiality of conservation of rare plants and their conservation status by IUCN
- To enhance the understanding on conservation and linking biotechnological tools in conservation programs
- To learn the recent theoretical and practical approaches towards conservation of germplasm

Unit –1 Conservation (12 hrs)

Introduction - Need for inventorying and documentation. Principles of conservation; extinctions; environmental distribution status of plants based on international union for conservation of nature (IUCN). Red data list of Indian plants.

Unit – 2 Plant conservation Biotechnology (12 hrs)

Integration of biotechnology into conservation practices. Molecular approaches to assessing plant diversity. Biotechnology in plant germplasm acquisition. Methods of Plant conservation, and sustainable utilization of plant genetic resources.

Unit – 3 Tissue culture techniques (12 hrs)

In vitro Plant Conservation: Culture room and lab facilities. Media composition and preparation – plant growth regulators, adjuvants; sterilization. Morphogenetic patterns. Callus culture - Subculture, differentiation, and regeneration. Organogenesis : Embryoids, Caulogenesis, Rhizogenesis, Cell Line, Somaclone, Gametoclone.

Unit – 4 Micro propagation (12 hrs)

Preparative stage: Germplasm acquisition and selection of explants. Establishment stage: Axenic and viable cultures. Multiplication stage. Plantlet production: induction of roots and acclimatization of plantlets to green house condition. Somatic embryogenesis. Synthetic seed technology. Suspension culture, in vitro production of secondary metabolites, cell immobilization.

Unit – 5Cryopreservation and Germplasm storage (12 hrs)

Slow or retarded growth. Principles, Cryoprotection, Freezing and long term cryogenic storage, protocols and recovery of germplasm. Conservation of Rare, endemic, threatened and economically important plants of India, current status and Active research stations in India. Stability assessments of conserved plant germplasm.

References

1. Dodds.I.H, and Roberts.L.W, 1995, Experiments in plant tissue culture. Cambridge University press, London.
2. Erica Benson. 1999, Plant conservation Biotechnology. Taylor and Francis Ltd., UK.
3. Dixon.R.A, 1994, Plant cell culture, A Practical approach.IRL press.Oxford, London.
4. Freifelder.D.1990.Molecular Biology.Narosa publishing house, New Delhi.
5. Murray Moo – Young. Plant biotechnology, comprehensive biotechnology series, pergamon press, Netherlands.
6. Narayanasamy.S, 1994, Plant cell and tissue culture. Tata McGraw – Hill Publishing co., Delhi.
7. Yeomen, 1987, Plant cell culture technology. Narosa Publication. New Delhi.
8. Lindsay, 1992, Plant Tissue Culture manual, Kluver Academic Publishers. Netherland.
9. George. E. F, 1994, Plant Propagation by Tissue culture. Exegetics Ltd., England.
10. Vasil.I.L, and Vasil.V.K, 1992, Plant Biotechnology and tissue culture. Kluver Academic Publishers, Netherlands.
11. Raven, Johnson, Losos, Mason and Singer 2008. BIOLOGY. 8th edition. McGraw Hill. New York, New Delhi.
12. Russell, Wolfe, Hertz and Starr 2008. Biology – THE DYNAMIC SCIENCE. Thomson Brooks/Cole, Australia, United States.

DEVELOPMENTAL BOTANY

L	C
60	4

UNIT I -MERISTEMS

Organization of Meristem – Stem (monocot & dicot) – root (monocot & dicot) cambium and secondary growth in dicots, anomalous secondary growth, Secondary thickening meristem in monocots. Microtechnique – anatomical fingerprinting. Histochemical localization of starch, proteins, oil and phenols. **13 HRS**

UNIT II – PLANT HORMONES

– Growth hormones and their role in development and resource mobilisation : Auxin, Cytokinin and Gibberellins- Functions and genetic molecular mechanism. **8 HRS**

UNIT III – DIFFERENTIATION AND MORPHOGENESIS

Cellular mechanisms of Development – overview of development- cell differentiation – pattern formation – morphogenesis – environmental effects on development. Growth and development through tissue culture – cell, tissue, organ culture – regeneration through somatic embryogenesis. **14 HRS**

UNIT IV – WATER AND FOOD MOVEMENT

Mobilization of food reserve – Pathway of upward movement of water and mineral ions – Mechanism of upward Movement in the xylem – Pathway of Movement of Organic Assimilates – Mechanisms of movement in Phloem. Cell wall architecture Mobilization of cell wall reserves (NSPs) in grasses. **12 HRS**

UNIT V – GENETIC CONTROL IN DEVELOPMENT

Gene expression with reference to plant development- Auxin response genes: Aux/IAAs, sUAR and GH3. Reactive Oxygen Species (ROS)- Nuclear gene expression: regulation by light. Differential gene expression in fruits and seeds. **13 HRS**

References

1. Raven, Johnson, Losos, Mason and Singer 2008. Biology. 8th edition. McGraw Hill. New York, New Delhi.
2. Russell, Wolfe, Hertz and Starr 2008. Biology – THE DYNAMIC SCIENCE. Thomson Brooks/Cole, Australia, United States.
3. Curtis (1935). The Translocation of Solutes in Plants. McGraw – Hill, New York.
4. Salisbury, Ross 1991. Plant Physiology. 4th edition. Brooks/Cole.

5. Richardson 1968. Translocation in Plants. The English Language Book Society and Edward Arnold (Publisher) Ltd.
6. Rudall 2006. Anatomy of Flowering Plants – An Introduction to Structure and Development. Cambridge University Press.
7. Mauseth 1988. Plant Anatomy. The Benjamin/ Cummings Publishing company, Inc. California.
8. Fahn 1967. Plant Anatomy. Pergamon Press. New York.
9. Lodish, Berk, Matsudaira, Kaiser, Krieger, Scott, Zipursky, Darnell. Molecular Cell Biology 5th edition.
10. Nicholl 2008 – An Introduction to Genetic Engineering 3rd edition. Cambridge University Press.
11. Primrose and Twyman 2006. Principles of Gene Manipulation and Genomics 7th edition. Blackwell.

PHYTOCHEMISTRY AND PHARMACOGNOSY

L	C
60	4

Objectives

- To have an understanding on the need for phytochemical studies which help to know the diversity of chemical compounds present in the plants.
- To learn the methods used in the extraction of the diverse compounds and their economic importance.
- To understand the need for pharmacological studies that help in the formulation of drugs for the benefit of humankind.
- To know the various analytical methods approved by WHO to standardize crude drugs.

UNIT- I Phytochemistry:

Scope, importance in pharmaceuticals industry, preparation of plant extracts - digestion, decoction, percolation, hot continuous extraction, aqueous alcoholic extraction, superficial fluid extraction and counter-current extraction. **(12 hrs)**

UNIT - II Secondary metabolites:

Definition, classification, natural sources and therapeutic applications of flavonoids: Flavones, Flavanones, Flavonols, Anthocyanins. Alkaloids: Ephedrine, Serpentine and Morphine. Volatile oils - source, constituents, extraction and uses. **(12 hrs)**

UNIT- III Glycosides:

Definition, properties, classification, natural sources, pharmacological and toxicological effects of glycosides. Terpenoids: β -Sitosterol, Glycyrrhizin. Phenolics: Coumarins and Tannins. **(12 hrs)**

UNIT-IV Pharmacognosy:

Definition, scope, Classification of drugs - morphological, taxonomical, pharmacological and chemical. Collection and processing of crude drugs - antichemical, phytochemical, antimicrobial and chemical. Preparation of plant extracts - maceration, infusion, decoction, percolation, sonication, hot continuous extraction, superficial fluid extraction and counter-current extraction. **(12 hrs)**

UNIT -V

Screening and WHO Standardization of crude drugs (WHO guidelines): Physicochemical (Ash and Extraction values), fluorescence analysis, qualitative and quantitative analysis, basic chromatographic and spectroscopic analysis of crude drugs. **(12 hrs)**

References

1. Agarwal, S.S and M. Paridhavi. 2007 Crude Drug Technology. Universities Press, Hyderabad
2. Anonymous, 1948-1976. The Wealth of India 11 Vols.
3. Bhattacharjee, S. K. 2004. Handbook on medicinal plants, Pointer publishers. Jaipur
4. Evans, W.C. 1997. Pharmacognosy. Harcourt Brace & Co., Asios Pvt., Ltd.
5. Faroogi, A.A and Sreeramu, B.S. 2001 Cultivation of Medicinal and Aromatic Crops, Universities press.
6. Gurdeep Chatwal 1983. Organic Chemistry of Natural Products. Himalaya Publishing house, Mumbai.
7. Joshi, S.G 2000. Medicinal plants, Oxford and IBH Company Private Ltd. New Delhi.
8. Kokate, C.K., Purohit, A.P. & Gokhale, S.B. 2007. Pharmacognosy. Nirali Prakashan, India.
9. Sharma, P. 2000. Database on Medicinal Plants used in Ayurveda. Ministry of Health and Family Welfare.
10. Srivastava, A. K. 2006. Medicinal Plants. International Book Distributors, Dehradun.
11. Tewari, K.S., Vishnoi, N.K., Mehrotra, S.N 1998 Text book Of Organic Chemistry. Vikas Publishing House Ltd.,
12. Wallis T.E. 1985. Text Book of Pharmacognosy. CSB Pub., New Delhi.
13. Yogaarasimhan, S.N. 2000. Medicinal Plants of India. Vol 2. Tamil Nadu., Inderline Publ. Pvt. Ltd., Bangalore and Dehra Dun.

BIOFERTILIZER AND PLANT RESPONSES

L	C
60	4

Objectives

- To enhance the understanding of the nutrient management and plant nutrient requirements
- To impart knowledge on the importance and mechanisms of the biological nutrient enhancement and availability to the plants.
- To reveal the application of potential biofertilizer agents currently used

Unit 1: Integrated Plant Nutrient Management (12 hours.)

Biofertilizers - classification, potential to improve crop production, chemically fixed Nitrogen versus biologically fixed nitrogen, and synergistic interaction between biofertilizing agents. Biofertilizing agents and plant disease control. Brief account of beneficial microorganisms – *Rhizobium*, *Azospirillum*, *Azotobacter* and mycorrhiza.

Unit 2: Nitrogen Fixation (12 hours.)

Historical review, biochemistry and regulation of biological nitrogen fixation, factors affecting nitrogen fixation, key organism fixing nitrogen - *Rhizobium*, *Azospirillum* and *Frankia*

Unit 3: Phosphate Solubilizing Microorganisms (12 hours.)

Phosphate fixation and solubilization in different soils. Factors affecting phosphate solubilization - mechanisms of action and role of acids. Biological phosphorus solubilization and effect on crop yield. key P-fixing fungal and bacteria with special emphasis on mycorrhiza.

Unit 4: Biofertilizer Application and Evaluation Techniques (12 hours.)

Different methods of biofertilizer inoculation - seed inoculation, top dressing of biofertilizers, granular biofertilizers, frequency of inoculation, liquid inoculation of biofertilizers, culture pellet, and methods of application of other biofertilizers. Preparation and use of inoculant - *Azotobacter*, *Azospirillum*, mycorrhizae, and *Rhizobium*. Role of humus in influencing the biofertilizer inoculation.

Unit 5: Crop Response to Biofertilizers (12 hours.)

Influence of symbiotic nitrogen fixation, *Azotobacter*, *Azospirillum*, and mycorrhizae in irrigated and dry crops and fodder crops. Factors affecting crop response to biofertilizers, interaction effect of microbial strains, effect of nutrient interactions, interaction of inoculants with other nutrients, multi-microbial inoculation and compatibility between biofertilizers and chemical fertilizers.

REFERENCES

1. Rai, M.K. (2006). Handbook of Microbial Biofertilizers, the Haworth Press, Inc
2. Kannaiyan, S. 2002. Biotechnology of Biofertilizers. Springer Netherlands, p.376.
3. Dubey, R.C. and Maheshwari, D.K. 2013. A Textbook of Microbiology (Revised edition). S. Chand & Company Ltd., New Delhi
4. Relevant Journal papers & Reviews

SOIL FERTILITY AND PLANT NUTRITION

L	C
60	4

Objectives

- To introduce the student with the problems of soil plant nutrient availability and the ways to manage and improve the productivity.
- To impart knowledge on the essentiality of the key elements of plant nutrition and the ways to enhance their availability in soil.
- To introduce the biological method of enhancing the nutrient availability and plant uptake

Unit 1: Soil as a medium for plant growth (12 hours.)

Abiotic and biotic elements of soils, formation of soil, classification and soil profiling. Characteristics and impact of acidic, saline, and alkaline soils on crop productivity. Importance of C: N ratio and pH in plant nutrition.

Unit 2: Soil fertility and productivity (12 hours.)

Soil properties on nutrient availability, definition of soil fertility in terms of productivity, soil types in wild and agrarian systems, soil patterns and agricultural regimes in Tamilnadu. Factors affecting soil fertility. Essential plant nutrients- NPK other major and minor nutrients, chelates. Classification of nutrients based on utilization and metabolic functions in plants. Criteria of essentiality of elements.

Unit 3: Plant Essential Nutrients (12 hours.)

Essential plant major and minor nutrient elements - functions, deficiency systems, biogeochemical cycles, transformations and availability. Effective consumption of nutrients, plant-microbe interface interactions in soils, positive and negative plant to plant interactions, changes in water table and its consequences.

Unit 4: Influence of microbes on plant nutrition (12 hours.)

Role of microorganisms in organic matter decomposition, and humus formation. Nitrogen fixation and cycling, phosphorus mobilization, calcium and potassium uptake and transport. Key microorganisms of nitrogen and phosphorus turnover in soil.

Unit 5: Fertilizer application (12 hours.)

Use of fertilizers, manures, mulch and bio supplements, concept of organic farming, and significance of green manure. Agricultural applications and dispensation of fertilizers- Methods of fertilizer application- solid and liquid forms of fertilizer application and their merits and demerits. Comparison of chemical and biological fertilizers on the basis of definition, application and crop protection potential. Analytical methods for soil nutrients.

REFERENCES

1. Western Fertilizer Handbook (9th edition). 2002. California Plant Health Association, Sacramento, Ca.
2. Brady, N.C. and R.R. Weil. 2005. The Nature and Properties of Soils (14th Ed.) Prentice-Hall, Inc.
3. Rai, M.K. (2006). Handbook of Microbial Bio fertilizers, the Haworth Press, Inc.
4. Benton Jones, Jr. J. 2012. Plant Nutrition and Soil Fertility Manual (Second Edition) CRC Press.
5. Journal review and research articles.

ECOLOGY, BIODIVERSITY AND SUSTAINABILITY

L	C
60	4

Objectives

- To gain knowledge on the biogeography, ecosystem diversity and biodiversity hotspots of India.
- To understand the concepts of vegetation analysis
- To understand the reasons for the loss of habitats/biodiversity and learn to find solutions to minimize degradation.
- To understand the need for the sustenance of habitats including man-made ones and conserve them for the benefit of humankind.
- To be aware of the existing social issues and the laws enforced to tackle the issues.

UNIT - I Biodiversity:

(12 hrs)

Introduction, definition, genetic and species diversity. Ecosystem diversity - Aquatic: ponds, lakes, streams, rivers, estuaries, oceans, desert ecosystem, grassland ecosystem, forest ecosystem, insular species diversity.

UNIT - II Biodiversity of India

(12 hrs)

India as a Megabiodiversity nation, Biogeographical classification of India, Biodiversity hotspots of India, Eastern Himalaya, Western Ghats, Eastern Ghats, Deccan Plateau, Gulf of Mannar, Andaman and Nicobar Islands. **Threats to biodiversity:** Habitat loss - Causes, effects and solutions; Poaching of wildlife - Causes, effects and solutions; Man-wildlife conflicts - Causes, effects and solutions; Endangered and endemic species of Peninsular India.

Unit-III: Vegetation Organisation and Diversity Analysis(12 hours)

Concepts of species, population and community; analysis of communities; community coefficients, inter specific associations, and concept of ecological niche; temporal and seasonal changes; island biogeography, and mangroves.

Ecophysiology and Diversity Analysis - Conceptual introduction; plant functional traits; phenological studies and their importance; analysis of density, species richness and diversity of plants; diversity indices; ecological genetics.

UNIT-IV Food and Agricultural resources and their conservation:(12 hrs)

Centres of origin of cultivated plants, Wild relatives of cultivated plants, Agriculture and food production, Agriculture and ecosystem degradation, Impacts of modern agriculture on environment - effects of fertilizers, pesticides, water logging and salinity, Sustainable agriculture and food production. Role of FAO.

UNIT – V Social issues and the environment:(12 hrs)

From unsustainable to sustainable development, Environmental ethics: issues and possible solutions, Consumerism and waste products, Environment Protection Act, Wildlife Protection Act, Forest Conservation Act, Issues involved in enforcement of environmental legislation, Public awareness. KYOTO protocols.

References

1. Annamalai, R. 2004. *Tamil Nadu Biodiversity Strategy and Action plan. Wild Plant Diversity*. Government of Tamil Nadu, Chennai.
2. Chapman, J.L. and Reiss, M.J. 1995. *Ecology: Principles and Applications*. Cambridge University Press, Cambridge.
3. Chhatwal, G.R. 1998. *Encyclopaedia of Environmental Biology*. Anmol Publications Pvt., Ltd. New Delhi.
4. Daniels, R.J.R. & Krishnaswamy, J. 2009. *Environmental Studies*. Wiley, India.
5. Dash, M.C. 2001. *Fundamentals of Ecology*, 2nd Edition. Tata McGraw Hill Publishing Company, New Delhi.
6. Gleason, H.A. & Cronquist, A. 1964. *The Natural Geography of plants*. University Press, New York.
7. Groom Bridge, B. 1995. *Global Biodiversity*. Chapman & Hall, London.
8. Krishnamurthy, K.V., Murugan, R. & Ravikumar, K. 2014. *Bioresources of the Eastern Ghats - their conservation and management*. Bishen Singh Mahendra Pal Singh, Dehra Dun.
9. Kumaresan, V. and Arumugam, N. 2015. *Plant Ecology and Phytogeography*. Saras Pub., Nagercoil.
10. Odum, E.P. & Barrett, G.W. 2005. *Fundamentals of Ecology*, 5th Edition, Affiliated East West Press Pvt. Ltd., New Delhi.
11. Odum, E.P. 1971. *Fundamentals of ecology*. W.B. Saunders Company, London.
12. Pullaiah, T., Karuppusamy, S. & Rani, S.S. 2014. *Biodiversity in India*. Vol. Astral International Pvt. Ltd. New Delhi.
13. Schulze ED, Beck E, Muller-Hohenstein K. 2005. *Plant Ecology*, First edition, Springer, Heidelberg, Germany
14. South Wick, C.H. 1976. *Ecology and the Quality of our Environment*. D. Van Nostrand Company, New York.
15. Turk, J. 1985. *Introduction to Environmental Studies*, 2nd Edition. Saunders College Publishers, Japan.

TAXONOMY OF ANGIOSPERMS

L	C
60	4

Objectives

- To improve the understanding of the taxonomy of angiosperms and its need
- To instill the significance of angiosperm taxonomy and its importance in conservation
- To prepare the students to become a researcher in angiosperm taxonomy

Unit I: Origin and evolution of Angiosperms (10 hours)

Ascent of angiosperms in geological time scale, major sites of origin. Theories with respect to time, place possible ancestors

Unit II: Plant nomenclature (13 hours)

Binomial Nomenclature, ICBN to IUCN; Methods of Botanical name(Latin)-Plant identification: Herbarium taxonomy, Botanical gardens, Taxonomic literature, Indented and Bracketed keys; Taxonomic hierarchy - Major categories, minor categories, species concept; Taxonomic evidences - Morphology, Anatomy, Palynology, Embryology, Cytology, Photochemistry, Genome analysis and Nucleic acid hybridization.

Unit III: Plant systematics and classification (13 hours)

Pre Darwinian Classification Based on form relationship (Bentham and Hooker); Post Darwinian classification Engler and Prantl, Bessey's, Hutchinson, Takhtajan and Cronquist; Recent modifications : Dahlgren's system of classification; Biosystematics Concept, aims and objectives, categories, methods in biosystematics, Ecotypic variations, scope and limitations, comparison of classical taxonomy and biosystematics; Angiosperm Phylogeny Group IV.

Unit IV: Numerical Taxonomy (12 hours)

Phenetic methods in taxonomy (taxometrics), principles, construction of taxonomic groups, OUTs, unit character, measurement of resemblances, cluster analysis, phenons and ranks, discrimination, nomenclature and numerical taxonomy, applications, merits and demerits, cladistics and cladogram, parsimony analysis, cladistics and classification

Unit V: Chemotaxonomy (12 hours)

Significance of chemotaxonomy, classes of compounds and their biological significance, uses of chemical criteria in plant taxonomy, protein and taxonomy, seed proteins, serology and taxonomy, application of serological data in systematic.

REFERENCES

1. Dunn G, Everitt ES. 2012. An Introduction to Mathematical Taxonomy, Dover Publications, New York
2. Singh G. 2016. Plant Systematics, Third Edition, Science Publishers, Plymouth
3. Sharma OP. 2016. Plant Taxonomy, 13th Reprint, Mc Graw Hill Education, New Delhi
4. Simpson MG. 2010. Plant Systematics, Second Edition, Elsevier Academic Press, USA
5. Scotland R, Pennington TR. 2000. Homology and Systematics, First Edition, Taylor and Francis, Philadelphia, USA
6. Stevens PF. 1999. The Development of Biological Systematics, First Edition, Columbia University Press, New York, USA
7. Forey PL. 1993. Cladistics: A Practical Course in Systematics, First Edition, Clarendon Press, UK
8. Gibbs RD. 1974. Chemotaxonomy of Flowering Plants: Families, Vol 2, First Edition, McGill Queen's University Press, Canada
9. Takhtajan A. 2009. Flowering Plants, First Edition, Springer-Verlag, Germany

PLANT ANATOMY AND REPRODUCTIVE BIOLOGY

L	C
60	4

Objectives:

1. Understand the types of tissues and their organization.
2. Compare the tissue components of vegetative and reproductive parts of a plant.
3. Principles of histochemistry and methods of localization of important chemical constituents.

Unit I Meristems

Types: Apical, lateral and intercalary. Tissue system: simple and permanent tissues. Complex tissues- xylem and phloem. vascular cambium origin, structure and development, seasonal activity of cambium, factors affecting cambial activity. (12 hrs)

Unit II stem anatomy:

Structure of a typical young dicot stem, normal secondary growth in a dicot stem. Leaf anatomy : structure and ontogeny of a dicot leaf, petiole anatomy. Anatomy of reproductive structure flower bud and mature flower. Nodal anatomy – Uni, tri and multilacunar node. (13 hrs)

Unit III Reproductive Biology

Floral structure, Pollination types – anemophily, hydrophily entemophily, ornithophily and chaerapterophily. Pollen pistil interaction and significance of the structure of style and stigma. (10 hrs)

Unit IV External secretory structures

Trichomes and glands, Nectaries, Hydathodes Internal secretory structures : secretory cells, secretory cavities and canals, laticifers. (10 hrs)

Unit V Histochemistry

Histochemical localization of cellular components - starch, Proteins Nucleic acids and lipids. Phytochemistry - basic concepts. Qualitative tests for alkaloids flavonoids, saponins, tannins, terpenoids and glycosides. (15 hrs)

References:

1. Eames A. J. and Mac Daniels L. H., 1990. An introduction to Plant Anatomy Tata McGraw Hill Publishing Company, Bombay-New Delhi. (Unit I & II).
2. Foster and Gifford .1967. Comparative morphology of vascular plants. Second edition. Valkis Feffer and Simons pvt. Ltd. Bombay.
3. Bhojwani,S.S. and Bhatnagar, S.P. 2005. Embryology of Angiosperms. vikas publishing house Pvt. Ltd., New Delhi. (Unit IV&V)
4. Esau K. 1991. Plant Anatomy. Wiley Eastern Limited. New Delhi.
5. Fahn. A .1987. Plant Anatomy. Pergamon press. New York.
6. Esau. K 1965. vascular differentiation. Halt Rinehart and Winston Inc United States.

7. Metcalfe, C.R. and L Chalk, 1965. Anatomy of Dicotyledons. Vol.II. Oxford University Press. London.
8. Maheshwari, P.1971. An Introduction to the Embryology of Angiosperms McGraw Hill Book Company, Inc., London.
9. Shivanna, R. Jobri. B.M. and Sastri. D.C. 1985. Development and physiology Angiosperm pollen. Wiley Eastern Ltd., New Delhi. (Unit IV & V).
10. Krishnamurthy, K.V. 1988. Methods in Plant Histochemistry. Viswanathan Printers Publishers Ltd., Chennai.

ALGAL TECHNOLOGY

L	C
60	4

Objectives:

- **To understand the concept and life cycle of algae.**
- **To learn the methods and approach towards the eco friendly aspects.**
- **To gain an insight on the various advancement in algal technology**

Unit:I - General account (12 Hrs)

Introduction: General account- Distribution, resources of algae. Classification of Algae (Fritsch,1935 &1945;Chapman and Chapman,1973;and Sybil and Parker,1981).Taxonomic Key for identification of economically important algae – Intended & Bracketed keys. Identification of algae in the field. Research centres of algae-Indian algalogists and their contribution: F.Boergeson. M.O.P Iyengar (1886-1963), M.S.Randhawa (1932-1959). and T.V.Desikachary (1919-2005) Role of Centre for Seaweed Herbarium & Marine Algal Research Station (MARS).

Unit: II-Structure and Reproduction of Algae(12 Hrs)

Structure and reproduction.- Range of Thallus structure , Patterns of reproduction and life cycle. Cell structure and organelles: Fine structure and functions. Chemical composition of marine algae-Macro & Micromolecules. Economic Importance of Algae.

Unit-III-Common Algal Pigments(12 Hrs)

Introduction- Common Algal Pigments : Structure and properties of some important algal pigments -Phycocerythrin, Phycocyanin, Beta-carotene, Chlorophyll and Fucoxanthin. Extraction of Algal Pigments and Role of Algal Pigments- Dyes and Colorants from Algae: Textile dyeing- Chlorophyll (*Caulerpa taxifolia.*) and Pharmaceutical dyeing- anthocyanin(*Spirulina sp.*) .

Unit-IV- Extraction, Processing and uses of Nutraceuticals (12 Hrs)

Phycocolloids: Agar-agar (*Gelidiella sp.& Gracilaria sp.*), Carageenan (*Hypnea sp. & Eucheuma sp.*), Algin (*Sargassum sp. & Padina sp.*) Omega-3 polyunsaturated fatty acids (*Nannochloropsis*). Nutraceutical tablets & tonic from *Spirulina sp.* and β -Carotene (*Dunaliella sp.*).

Unit-V- Commercial products from algae:(12 Hrs)

Preparation and applications of the Following: Salad & Soup (*Ulva, Caulerpa*) Jelly, Candy, Gelatin, Food thickeners, Sushi, (*Gracilaria sp.*) Tooth paste (Carageenan- *Euchuma sp.*). Seaweed Liquid Fertilizer (*Sargassum sp.*), Biomedicine: Caulerpin, Caulerpicin (*Caulerpa sp.*) and Heparin (*Grateloupia sp.*)

Text Books :

1. Ashutosh Kar (2010) . Chemistry of Natural Products, Vol. 1 CBS Publishers and Distributors Pvt Ltd, e-book.
2. Boergeson, F. (1938). Contributions to the South Indian marine algal flora. III. J. Indian Bot. Soc. 17: 205 -242.
3. CMFRI Bulletin: 40., (1998). Seaweed culture, Processing and utilization, Tatapuram, Cochin.
4. Fritsch, F.E. (1935) The Structure and Reproduction of the Algae ; Volume 1, First Edition . Cambridge University Press
5. Fritsch F. E. (1952) The Structure and Reproduction of the Algae ; Volume 2, First Edition. Cambridge University Press.
6. Ganguly, H.C., Kar, A. K., and S.C. Chandra (2013) College Botany, Vol-I, New Central Book Agency PVT. London.
7. Khattar, J.I.S., Singh, D.P., Kaur, (2009) Algal Biology and Biotechnology, - Microalgae: A source of natural colours, Edition: 1, I. K. International Publishing House Pvt. Ltd. New Delhi,
8. Laura Barsanti, Paolo Gualtieri. 2014 Algae: Anatomy, Biochemistry, and Biotechnology, Second Edition. CRC Press. London.
9. Leela, S.S and Jyothi Kumar, 2010. Algal BioProcess Technology, 1st Edition, New age International Publishing house, New Delhi.
10. NIIR Board of Consultants & Engineers.. ISBN: 8178330326. Code: NI160. Pages: 448. Published: 2005. The Complete book on Natural Dyes & Pigments. Publisher: Asia Pacific Business Press Inc. e-book..
11. Pandey B.P., (2000). Revised edition, *Text Book of Botany Algae*, S.Chand & Company, New Delhi .
12. Vashista. P.C. (1996). Text book of Algae, S.Chand Publishers, Meerut.
13. Venkatataman, G.S. (1962). Algal Biofertilizer and Rice cultivation, 8th Edition, Today and Tomorrow Publishers, New Delhi.

BRYOPHYTE SYSTEMATICS AND EVOLUTION

L	C
60	4

Objectives

- To gain knowledge on the origin, evolution and distribution of bryophytes including fossil evidences globally.
- To have a knowledge on habitat preferences, diversity of bryophytes and factors influencing their growth.
- To have a brief knowledge on the morphology, anatomy and life-cycle of bryophytes.
- To be aware of the factors responsible for their loss and find measures to minimize them.

UNIT - I

Origin and evolution: Origin and distribution, Fossil bryophytes, Evolution of gametophytes, Evolution of sporophytes, Primitive and advanced features of bryophytes. **(12 hrs)**

UNIT-II

Diversity: Classification of bryophytes, Diversity, Habitat diversity, Factors influencing the growth of bryophytes, Ecological adaptations. **(12 hrs)**

UNIT-III

Mosses: A comparative study of the morphological and anatomical features of Sphagnales, Polytrichales, Fissidentales, Syrrhopodontales, Funariales, Eubryales, Hookeriales and Hypnobryales. **(12 hrs)**

UNIT-IV

Liverworts: Calobryales, Sphaerocarpaceae, Marchantiales, Metzgeriales Jungermanniales and Anthocerotales. Economic importance of bryophytes. **(12 hrs)**

UNIT-V

Special features: Life-cycle of bryophytes, types of sporogonia/elaters, gemmae/receptacles, calyptrae and operculum and peristome teeth. **(12 hrs)**

References

1. Cavers, F. 1981. The Interrelationships of the Bryophyta. Indian report S.N. Technico (Book House), Patna.
2. Chopra, R.N. & Kumar, P.K. 1988. Biology of Bryophytes. Wiley Eastern Ltd., New Delhi.
3. Daniels, A.E.D. & Daniel, P. 2013. The Bryoflora of the Southernmost Western Ghats, India. Bishen Singh Mahendra Pal Singh, Dehra Dun.
4. Puri, P. 1981. Bryophytes. Atma Ram & Sons, New Delhi.

5. Watson, E.V. 1980. British Mosses and Liverworts. Cambridge.

ETHNOMEDICINE

L	C
60	4

- To have an insight into the various Indian Systems of medicine.
- To have a knowledge on the plants used in these systems.
- To understand the ethical values of plants involved in these systems.
- To develop methods of conservation of medicinal plants.

Unit-1 Ethnomedicine (12 hrs)

Definition, role of tribal communities in Ethnomedicine. Historical account of medicinal plants in India. Classification of medicinal plants on the basis of morphological structure viz. leaf, root, stem, rhizome, flower, fruits and seeds. Religious values of plants, faith and mythology, folk songs, plants used in rituals, tribals and medicinal plants, Holy plants in ethno medicine.

Unit-2 Distribution and Status (12 hrs)

Medicinal plants in general, distribution in Western Ghats and Eastern Ghats. Medicinal plants of Tamil Nadu: Endemic, rare and endangered species of medicinal plants.

Unit-3 Conservation (12 hrs)

Collection and conservation of medicinal plants. Sacred groves, Herbal farms, Nurseries, Medicinal gardens, Plants in Temples, Churches and Mosques. A general account of active principles found in the medicinal plants of *Aegle*, *Coriandrum*, *Cuminum*, *Piper*, *Brassica*, *Catharanthus*, *Artemisia*, *Coleus*, *Trichopus*, *Wrightia*, *Azadirachta* and *Taxus*.

Unit-4 Systems of Medicine (12 hrs)

History of Ayurvedic medicine, Ranges of Ayurveda, Significance and plants used in Ayurveda. Principles of Unani medicine, diagnosis and mode of treatment, Unani approach to common ailments. Difference between Ayurvedic and Unani medicines, safety measures in Unani medicines and plants used in Unani system.

Unit-5 Herbal remedies (12 hrs) for Gynaecological morbidity, plants in the treatment of diabetes, herbal remedies for liver diseases, Plants in the treatment of skin diseases, antivenomic and antitoxic plants.

Reference Books

1. Gurdeep Chatwal, 1983. Organic chemistry of Natural Products, Himalaya Publishing

- House, Mumbai.
2. Jean Bruneton, 1999. Pharmacognosy, Second Edition, Lavoisier Publishers, Inc. USA.
 3. Kokate, C.K., Purohit, A.P and Gokhale, S.R. 2004. Pharmacognosy, Nirali Prakashan Publications, Pune.
 4. Nitin Suri, 2010. Phytochemical Techniques, Oxford Book Company.
 5. Roseline, A. 2011. Pharmacognosy, MJP Publishers, Chennai.
 6. Rमित M Shah and Rupesh T Nayak, 2012. Pharmacognosy, Global Academic Publishers, New Delhi. (Part I and Part II).
 7. Wallis, T.E. 1985. Text Book of Pharmacognosy, CSB Publishers, New Delhi.
 8. William Charles Evans, 2002. Pharmacognosy, Fifteenth edition, Harcourt Brase & Company, Asia Pvt. Ltd.
 9. Anonymous, 1987. The Wealth of India, (vol. 1-11). CSIR, Directorate Publications, New Delhi.
 10. Bhattacharjee, S.K. 2004. Handbook on medicinal plants, Pointer Publishers. Jaipur.
 11. Sharma P. and C.Etal, 2000. Database on medicinal plants used in Ayurveda, Ministry of Health and Family Welfare.
 12. Yogaarasimhan S.N. 2000. Medicinal plants of India, Vol 2. Tamil Nadu., Inderline Publishing Private Ltd. Bangalore, Dehra Dun and Michigan.
 13. Joshi, S.J. 2000. Medicinal Plants. Oxford & IBH company Pvt. Ltd., New Delhi.
 14. Michael, A.M. Handbook of Medicinal plants. Pointer Pub., Jaipur.
 15. Warriar, P.K., Nambiar, V.P.K & Ramamurthy, C. 1996. Indian Medicinal plants. Vols. 1 - 5. Orient Longman Ltd., Hyderabad.

MARINE BOTANY

L	C
60	4

OUTCOMES

- Students will be introduced to marine and estuarine environments
- Students will become familiar with the major micro- and macro- algal groups and marine vascular plants.
- Students will appreciate the roles played by algae, seagrasses and aquatic vascular plants in aquatic ecosystems.
- Students will become aware of how natural events and human activities affect coastal habitats

UNIT: I

(12 hrs)

Marine plant groups and Organisms – Brief account on Marine Phytoplankton – Seaweeds, Seagrasses and Mangroves – Corals and coral reefs. Mangroves – adaptations of marine plants.

UNIT: II

(12 hrs)

Marine Ecology – Physical, chemical and biological characteristics of marine water. Zonations in the oceans (Horizontal and vertical) - Dead zones (Anoxia and Hypoxia) - Tides and their importance.

UNIT: III

(12 hrs)

Photosynthesis of algae (Micro and macro) in sea – Photosynthetic pigments – carbon fixation – Photosynthetic rate – C₃ and C₄ characters in algae. Photosynthesis of mangroves – carbon fixation – Photosynthetic enzymes – accumulation of free amino acids – photorespiration – Nutrition – Salinity regulation and Metabolism of Seaweeds and Mangroves and their methods of regeneration – Biogeochemical role of algae.

UNIT: IV

(12 hrs)

Seaweed Polysaccharides – Commercial and economical products of Seaweed (Agar, Algin and Carrageenan) and Low molecular weight compounds in algae – Methods of collection and preservation of Marine algae – Commercial cultivation of seaweeds (Traditional and Recent methods) – Application and uses of Seaweeds - Economic importance of seaweeds.

UNIT: V

(12 hrs)

Seaweed, Sea grasses, Mangroves and Coral reefs research in India and World. Marine Pollution – human Impact - Conservation strategies of Marine vegetation - Use of Remote sensing techniques in mapping of marine vegetation with GIS.

REFERENCES

- 1. Jackson, D.F. 1972.** Algae and Men. Plenum Press.
- 2. Krishnamurthy, V. 1985.** Marine Plants. Seaweed Research and utilization Association, madras.
- 3. Chapman, V.J. 1976.** Coastal Vegetation. Pergamon press. New York.
- 4. Daves, C.J. 1985.** Marine Botany Physiology and Ecology of Seaweeds.
- 5. Dawson. 1960.** Marine Botany.

VASCULAR CRYPTOGAMS

L	C
60	4

OUTCOME

- An understanding the diversity, life-cycle patterns and major evolutionary trends of Pteridophytes and gymnosperms.
- An understanding of the diversity of pteridophytes and gymnosperms
- An understanding of the evolution of pteridophytes and the fossilization process.

UNIT: I General characters of Pteridophytes

(12 hrs)

General life cycle pattern of homosporous and heterosporous pteridophytes. General ecology of Pteridophytes. Contributions of Indian Pteridologists.

UNIT: II Pteridophyte classification

(12 hrs)

A R Smith *et al.* General morphological, anatomical and reproductive characters of major classes of pteridophytes.

UNIT: III Evolution

(12 hrs)

Cytological evolution in pteridophytes; apogamy and apospory; mechanism of diplospory in apogamous ferns (Dopp and Manton, Braithwaite system).

UNIT: IV Steels

(12 hrs)

Stelar types and stelar evolution, sporangial/soral types and sporangial/soral evolution in pteridophytes.

UNIT: V Pteridophytes of India.

(12 hrs)

Pteridophytes in India:- Rare and endangered species in Western Ghats, South India. Medicinal pteridophytes; Conservation of pteridophytes in India.

REFERENCES

1. **Sporne, K.R. 1985.** The Morphology of Pteridophytes, Hutchinson & Co, London.
2. **Pandey, B.P. 1978.** Pteridophyta. S. Chand & Company Ltd., New Delhi.
3. **Vashista, P.C. 1997.** Pteridophyta. S. Chand and Company Ltd., New Delhi
4. **Rashid, A. 1990.** An introduction to Pteridophyta. Vikas Publishing House Pvt. Ltd., New Delhi.
5. **Manickam, V. S. & Irudayaraj, V. 1992.** Pteridophyte Flora of the Western Ghats,

South India. BI Publications, Pvt. Ltd. New Delhi.

6. **Manickam, V. S. & Irudayaraj, V. 2003.** Pteridophyte Flora of Nilgiris, south India. Bishen Singh & Mahendra Pal Singh. Dehradun, India.
7. **Nayar, B. K. & Kaur, S. 1971.** Gametophytes of homosporous ferns. *The Bot. Rev.* 37: 295-396.
8. **Pullaiah, T. 2003.** Pteridophytes in Andhra Pradesh India. Daya Publishing House, India.
9. **Smith *et al.*, 2006.** A classification of extant pteridophytes. *Taxon* 55(3): 705-731.
10. **Schneider *et al.*, 2016.** A community-derived classification for extant lycophytes and ferns. The Pteridophyte Phylogeny Group. *J. Syst. & Evol.* 54: 563-603.