VISION

The study of Botany, dealing with the structure, function, classification and evolution of plants, has inspired many great minds. Plants are unique as solar energy converters and providers of energy for all heterotrophic organisms. Their biological services are legion. One is awed by the extreme variations encountered in their size and shape, from unicellular algae to huge trees with a life span extending from a few months to thousands of years. The life strategies of plants are quite distinct from those of animals. They occur wherever some water and light are available. Being unable to move, they cannot escape stresses and have to adapt themselves to survive by physiological mechanisms and not by behaviour. Lacking a central control mechanism such as a brain, nervous system or a circulatory system, it is amazing how large trees can organize themselves with such extraordinary harmony. The forms of leaves, the structure and coloration of flowers and the range of adaptive capacity varies in members belonging to different families, genera and species. It is fascinating to study the wide spectrum of reproductive processes in algae, fungi (classified under a separate kingdom but still taught in the departments of Botany), lichens, bryophytes, fern allies, gymnosperms, and flowering plants. Sexual reproduction ensures genetic recombination and heterozygosity, which are necessary to prepare the progeny for the ever-changing environment. Plants can also survive through vegetative propagation. Cellular totipotency is a highly developed endowment in plants. A student of botany has been learning these aspects together with taxonomy, anatomy, physiology, ecology, cytology, genetics and plant breeding through various course curricula developed by different Universities. We recognize that in a majority of colleges and universities inputs of modern biology are highly inadequate. The last few decades have ushered in new advances, as briefly described below, not only in general biology, but also in plant sciences, which now need to be incorporated in the present Botany/Plant Sciences curricula at various levels of education in the Colleges and Universities.

Modern biology could be traced to the seeds of the garden pea plant, *Pisum sativum.* It was the experimentation of a European monk, Gregor Mendel, in breeding pea plants in a monastery in Brno (now in Czeck republic) that inspired further research in the study of genetics that eventually led to the discovery of DNA and the exciting era of molecular biology and genetic engineering.

The 20th century witnessed some of the greatest advancements in the area of genetics and molecular biology: the establishment of DNA as the genetic material and the central dogma – DNA to RNA to proteins; the elucidation of the structure and replication of DNA and the decoding of the genetic code that determines the fate of an organism. During the last century technological advancements were put on high horizon. DNA could be spliced and rejoined

precisely and the genetic material could be shuttled across and the species barriers could be broken. Hundreds of proteins could be crystallized and their structures determined and functions analyzed. Other molecules, like carbohydrates and lipids, were studied with greater precision to understand their role in cell functions. Advancements in molecular biology came at such a fast pace that many were taken by awe and surprise to discover the details of the functioning of molecules, organelles and cells. The broad laws and minute rules that govern the growth and development of organisms were also brought to light towards the end of the last century.

A quantum jump in the race to elucidate the functions of all the proteins encoded in the genetic material in an organism was possible when scientists and intelligent machines they had invented started putting their efforts together. The end of the last century saw the growth of sequencing machines in various laboratories all over the developed world rolling down millions of A, T, G and C's of bacterial, plant and animal DNA. And now with the announcement of a draft sequence of all the DNA of *Homo sapiens sapiens*, the human race has taken pride in not only making achievements in voyaging into the outer space and landing man on the moon, but also in looking inside its own genome to understand the basis of human development, diseases and behaviour.

The basic cellular machinery and house-keeping functions are similar in all organisms (plant and animal kingdom). Yet there are fundamental differences. Being stationary, with the exception of a few motile aquatic forms, plants have developed an intricate organelle – the chloroplast – which helps it to synthesize food for its own development by photosynthesis. The plant cells have a unique cellulose wall around the membrane, which performs, as is now being shown, both a structural and a functional role. The structure and function of plasmodesmata are revealing new ways of material transfer and communication between plant cells. Plants can also sense the environment, like light, using a set of photoreceptors called phytochromes and cryptochromes, and temperature, using two-component histidine kinase sensor systems and also the soil conditions like moisture stress, ions etc, with precision. These features help plants to respond and adapt themselves to specific environmental conditions.

The molecular basis of plant development, from seed germination to flowering and to seed and fruit formation, have been worked out in considerable detail in at least some plants such as *Arabidopsis* (the *Drosophila* of the plant world), maize, and rice. Today, a large number of genes that take part in embryogenesis, leaf formation, root development, flowering (pattern, timing and number) have been examined in depth. Certain genes and proteins that take part in chloroplast development and photosynthetic functions (these are encoded both by nuclear and chloroplast genome), are now known. In fact, the total sequence of chloroplast genome has been reported from over a dozen lower and higher plants. The genes that specifically respond to various environmental factors, under normal conditions and also under biotic and abiotic stress conditions, have been catalogued from many plant species.

The mechanism of pathogenesis and disease resistance has been elucidated in a number of cases. In addition, the structure and functions of enzymes and their encoding genes, which take part in various metabolic processes, like nitrate uptake and reduction, and phosphate metabolism have been demonstrated. Plants synthesize over 100,000 secondary products, some of which are useful to humankind as medicines (artemisinin, taxol, ginkgolides, vincristine, vinblastine, etc.) or other economic products, such as rubber. Several laboratories are engaged in finding the molecular regulation of metabolic pathways of these compounds. There has been an overall advancement in plant molecular biology to understand the molecular basis of development, metabolism, perception of environmental factors and signal transduction in all groups of plants. More information is expected to flow in the next few years since *Arabidopsis* genome has now been sequenced and rice genome will also be sequenced in next two years. It is hoped that the job of each protein within the cell will be understood not before long. In future, when more data become available from other plants, we will be better equipped to find out the relationships between various families and taxa and be able to deal with subjects such as biodiversity, taxonomy, conservation and evolution with greater precision. A consequence of all these research activities will be the development of novel plants through biotechnological means that will meet the future requirements of humans and their domesticated animals and to reap the undiscovered benefits of plants.

It is not only in flowering plants but also in the lower plants that exciting new discoveries are being made. The total sequence of a blue-green alga, *Synechocystis*, has been accomplished and knockout mutants of various ORFs (Open Reading Frames) are available. The genome sequence of *Neurospora* and *Chlamydomonas* will be completed in a few years from now. The molecular investigations on the moss *Physcomitrium* are turning out to be crucial for understanding gene function.

Great thinkers in biology are constantly debating the consequences of new knowledge in terms of evolutionary wisdom. We congratulate ourselves on the historic accomplishment of sequencing of the human genome. The genome itself has made us realize that we are not so special after all. We have five times as many genes as a bacterium, a third higher than a worm and about twice as many a fly. Around 90% of our genes are similar to those in a mouse. We differ from chimpanzees by only 1% in our DNA. These findings teach us to be humble and importantly provide the physical evidence of genetic connectedness of all organisms on this planet and to develop a new empathy with them. These also raise the question of how small differences in DNA may create large dissimilarities.

The study of biodiversity and ecology has opened our minds to another hard reality. One highly successful and adaptive species *Homo sapiens sapiens* is ruthlessly destroying others and their habitats at a rate and on a scale that has no precedence. Although nearly 99% of all the organisms that were even formed on this planet are extinct, we do not have a real count of the enormous number of living forms today. It could be anything between 2 million to 100

million. Only about 1.7 million organisms have been described and named. There is thus much scope for exploration of new plants of unknown value and old plants known to us through traditional systems of medicine with new uses. Attempts are being made to conserve wild life *in situ* by declaring vast tracts of land as protected areas. These include biosphere reserves, national parks and sanctuaries. *Ex situ* conservation involves establishment of zoos, botanical gardens, field gene banks, seed banks, tissue culture repositories and cryobanks. Also large tracts of land have become transformed into unproductive ecosystems. Mined areas and intensely grazed lands exemplify dead ecosystems. Restoration ecology requires the technologies involving a consortium of microbes and grasses and leguminous weeds that enable subsequent introduction of suitable trees and shrubs. Intellectual property rights (IPR) are becoming increasingly important in a biodiversity rich country like India in the post-GATT scenario to protect plants that have useful gene products.

Poverty and hunger have no place today but they still exist. Habitat destruction, overuse of energy and resources and pollution have been mainly responsible for the irretrievable loss of a large number of species. According to some estimates, unless drastic measures are immediately taken 50% of all life on earth may be wiped out by the end of the present century. Modern economics does not put a true value on the environment. Being in close touch with nature is crucially important to bring collective changes at the governmental and political level. The students of today have lost touch with the natural world and have accepted highly consumerist life styles.

Taking a balanced view of the exciting new knowledge that is being generated with immense possibilities on the one hand and the hard realities of the global environmental crisis on the other, we have decided to revise the Botany/Plant Science course curricula for B.Sc. (General), B.Sc. (Hons) and M.Sc. In doing this, we have introduced some new courses in theory and practice with a greater emphasis on field work. This has necessitated addition of new topics in the existing courses. The result is a modification of overall course structure, which we hope will be beneficial to the students of botany in the overall context of biology education. We are conscious that syllabi can not afford to be static. What has been evolved is the outcome of ideas of a few individuals entrusted with a specific responsibility. We are deeply conscious that there are bound to be gaps between the ideal and real. Genuine endeavor is required to minimize the gaps by intellectual and material inputs. Different Universities may modify the overall structure based on their strengths. However, we hope that the course contents are not diluted. The success of this course will depend on the initiative and drive of the teachers and the receptive students.

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December, 2001

V.S. Jaiswal
Nodal Person
CDC for Botany

INTRODUCTION

The University Grants Commission undertook the first massive exercise of curriculum development in all disciplines exactly a decade ago. It involved hundreds of University and College teachers and took almost one year for completion. The exercise was necessitated by the wide diversity in the curricula of different Indian universities (which, apart from other things, inhibits mobility of students), lack of complimentarity between the Honours and General Degree Courses and subsidiaries, inadequate coverage of advancements in knowledge and mismatch in lectures, laboratory and field work.

The Curriculum Development Committees (CDCs) constituted for various subjects were entrusted the job of evolving curricula which would make up the inadequacies referred to above and provide for mobility of students from one institution to another. After threadbare debates, consultation of the curricula in operation then and taking note of the state of the art in the subject, all CDC's, including that of Botany, developed curricula, which the UGC circulated among the universities for adoption through their academic bodies in entirety or in part.

No feedback has been collected from universities and reviewed by the Commission to ascertain the impact made by these curricula. Personal knowledge of the members of the present CDC in Botany is that the response has been varied; whereas some elite Departments found the national syllabi not up to the mark compared to their own, others ignored syllabi partly out of indifference and partly for want of infrastructure and trained humanpower in certain areas of modern biology. A few universities partially adopted new course contents for various reasons. As a consequence, the diversity, which existed before 1991, when the new curricula were formulated, persists even today.

Existing Curriculum

Barring a few exceptions the existing syllabi do not reflect, in ample measure, the tremendous advances mode in Biology. They also do not aim to identify and deliberate on national concerns and priorities. It is, therefore, no wonder that a sizeable number of graduates and post-graduates that Indian universities churn out year after year lack the capability to find a foothold in life and become instruments of change. Many of the graduates remain unemployed for unduly long time or land up in jobs remotely connected with the discipline in which they hold a University Degree. This works as a damper for those who are in the process of making the choice of a career. Although it is impossible to expect at any time that the graduates will be assured of openings in the areas of their study, education at the degree level must ensure that they receive the academic rigour, the ability to function systematically and objectively, retain curiosity, and develop competence to learn to learn, learn to work and learn to live.

In realization of these facts and also because curriculum development is a continuous process, the UGC has undertaken the exercise of curriculum development at under-graduate and post-graduate levels once again. CDCs were constituted in the year 2000. The CDC in Botany has seven members from universities and one from college (see p. 10). The members are specialists in different areas of plant sciences; this has helped in evolving, what we consider, a balanced curriculum. The Committee has met five times in the UGC office to discuss the drafts prepared by individual members and has developed the final draft after critical discussions.

The members of the Botany CDC had a couple of sittings with Professor A. Nigavekar, Vice-Chairman, UGC to acquaint themselves with the aims and objectives of Curriculum Development. Through the discussions that were held, it emerged that the objectives are, more or less, similar to those of the previous exercise. These are listed below.

Objectives

i. To ensure a more or less equal weightage of curricula at the under-graduate and post-graduate levels (which is presently lacking) as the duration of B.Sc. and M.Sc. programmes is the same all over the country;

ii. To identify and delimit core courses and electives, which at some places are determined entirely by the expertise of the available staff and not necessarily by the importance and relevance of the area;

iii. To update course contents by introducing in good measure recent developments in plant sciences to ensure that students of this country do not have any academic disadvantages over their counterparts overseas;

iv. To ensure that the curricula are not overloaded by minimizing the descriptive aspects and eliminating repetition of contents between higher secondary, under-graduate and post-graduate syllabi;

v. To provide the students of Master's programme in Botany an opportunity to opt one or more courses in allied disciplines to help them pursue specialization/research in interdisciplinary areas;

vi. To make provision for improvement in the quality of laboratory and field work for want of which the students are not able to appreciate the beauty and variety of form, structure, function and ecological significance of plants and their biological services;

vii. To increase the awareness of young learners about the abuse to which plants have been subjected by human greed, and train them in exploration, identification and evaluation of plants, conservation of nature and natural resources and in the protection of endangered plant species and other biota dependent on them;

viii. To prepare the curriculum such that it can attract, enthuse, sustain and promote the interest of learners for selecting Plant Science and allied disciplines as their career and make them realize that their choice is intellectually rewarding, and

ix. To provide for mobility of students among institutions and different disciplines.

NEW PROPOSED CURRICULA – AN OUTLINE

M.SC. (BOTANY)

First Year

Course I. Cell and molecular biology of plants

Course II. Cytology, genetics and cytogenetics

Course III. Biology and diversity of lower plants: cryptogams

Course IV. Taxonomy and diversity of seed plants

Course V. Plant physiology and metabolism

Second Year

Course VI. Plant development and reproduction

Course VII. Plant ecology

Course VIII. Plant resource utilization and conservation

Course IX. Biotechnology and genetic engineering of plants and microbes

Course X. Elective

B.SC. (GENERAL)

First Year

Course I. Diversity of microbes and cryptogams

Course II. Cell biology and genetics

Second Year

Course III. Diversity of seed plants and their systematics

Course IV. Structure, development and reproduction in flowering plants

Third Year

Course V. Plant physiology, biochemistry and biotechnology

Course VI. Ecology and utilization of plants

B.SC. (HONOURS)

First Year

Course I. Diversity and classification of the plant kingdom

Course II. Cell biology and basic biochemistry

Second Year

Course III. Plant physiology and ecology

Course IV. Development of plants and their utilization

Third Year

Course V. Biology of cryptogams

Course VI. Biology of seed plants

Course VII. Microbiology and plant pathology

Course VIII. Genetics and plant breeding

Course IX. Biochemistry, molecular biology and biotechnology

Course X. Systematics of angiosperms and environmental biology

CALCULATION OF TEACHING LOAD

Total number of working days	: 180 per year
Total number of teaching days (minus examination and and preparatory days)	: 160 per year
Teaching load	: 6 hours per day
Total teaching load	: 160x6 = 960 hours per year or 480 hours per semester

Note:

1. The course content has been designed on annual pattern. For semester system in M.Sc., tentative titles have been given. Accordingly, the course content can be distributed as per the convenience of respective Universities/Departments.
2. For B.Sc.(General) teaching load is given on annual pattern.
3. B.Sc. (Hons) : Since the pattern is variable, the work load for theory/practicals be calculated by respective Departments on the pattern given above.

M.SC. (ANNUAL PATTERN)

1st Year		Theory Hours	Practical
Course I	Cell & Molecular Biology of Plants	50	120
Course II	Cytology, Genetics & Cytogenetics	50	120
Course III	Biology & Diversity of Lower Plants : Cryptogams	50	120
Course IV	Taxonomy & Diversity of Seed Plants	50	120
Course V	Plant Physiology & Metabolism	50	120
	Total	**250**	**600**

Theory : 250 hours
Practical : 600 hours
Tutorials/Seminars : 110 hours
TOTAL **960 hours**

2nd Year			
Course VI	Plant Development & Reproduction	50	120
Course VII	Plant Ecology	50	120
Course VIII	Plant Resource Utilization & Conservation	50	120
Course IX	Biotechnology & Genetic Engineering of Plants & Microbes	50	120
Course X	Elective/Project Work	50	120
	Total	**250**	**600**

Theory : 250 hours
Practical : 600 hours
Tutorials/Seminars : 110 hours
TOTAL **960 hours**

M.SC. (SEMESTER PATTERN)

I Semester		**Theory** Hours	**Practical**
Course I	Cell Biology of Plants	25	60
Course II	Molecular Biology of Plants	25	60
Course III	Biology & Diversity of Viruses, Bacteria & Fungi	25	60
Course IV	Biology & Diversity of Algae, Bryophytes & Pteridophytes	25	60
Course V	Cytology & Genetics	25	60
	Total	**125**	**300**

Theory : 125 hours
Practical : 300 hours
Tutorials/Seminars : 55 hours
TOTAL : **480 hours**

II Semester			
Course VI	Genetics & Cytogenetics	25	60
Course VII	Biology & Diversity of Gymnosperms	25	60
Course VIII	Taxonomy of Angiosperms	25	60
Course IX	Plant Physiology	25	60
Course X	Metabolism	25	60
	Total	**125**	**300**

Theory : 125 hours
Practical : 300 hours
Tutorials/Seminars : 55 hours
TOTAL : **480 hours**

III Semester		**Theory** Hours	**Practical**
Course No. XI	Plant Development	25	60
Course No. XII	Plant Reproduction	25	60
Course No. XIII	Plant Ecology-I	25	60
Course No. XIV	Plant Ecology-II	25	60
Course No. XV	Plant Resource Utilization	25	60
	Total	**125**	**300**

Theory : 150 hours
Practical : 300 hours
Tutorials/Seminars : 55 hours
TOTAL : **480 hours**

IV Semester			
Course No. XVI	Plant Resource Conservation	25	60
Course No. XVII	Biotechnology-I		
	or		
	(Plant Cell, Tissue & Organ Culture)	25	60
Course No. XVIII	Biotechnology & Genetic Engineering II		
	or		
	(Genetic Engineering of Plants & Microbes)	25	60
Course No. XIX	Elective-I/Project Work	25	60
Course No. XX	Elective-II/Project Work	25	60
	Total	125	300

Theory : 125 hours
Practical : 300 hours
Tutorials/Seminars : 55 hours
TOTAL : **480 hours**

B.SC. GENERAL (ANNUAL PATTERN)

Ist Year		**Theory** Hours	**Practical**
Course I	Diversity of Microbes & Cryptogams	60	100
Course II	Cell Biology & Genetics	60	100
	Total	**120**	**200**
		Theory : 120 hours	
		Practical : 200 hours	
		TOTAL : **320 hours**	
IInd Year			
Course III	Diversity of Seed Plants & their Systematics	60	100
Course IV	Structure, Development & Reproduction in Flowering Plants		60 100
	Total	120	200
		Theory : 120 hours	
		Practical : 200 hours	
		TOTAL : 320 hours	
IIIrd Year			
Course V	Plant Physiology, Biochemistry & Biotechnology	50	110
Course VI	Ecology & Utilization of Plants	50	110
	Total	**100**	**220**
		Theory : 100 hours	
		Practical : 220 hours	
		TOTAL : **320 hours**	

Detailed Curriculum

of

M.Sc.

COURSE I. CELL AND MOLECULAR BIOLOGY OF PLANTS

The dynamic cell: Structural organization of the plant cell; specialized plant cell types; chemical foundation; biochemical energetics.

Cell wall: Structure and functions; biogenesis; growth.

Plasma membrane: Structure, models, and functions; sites for ATPases, ion carriers, channels and pumps; receptors.

Plasmodesmata: Structure; role in movement of molecules and macromolecules; comparison with gap junctions.

Chloroplast: Structure; genome organization; gene expression; RNA editing; nucleo-chloroplastic interactions.

Mitochondria: Structure; genome organization; biogenesis.

Plant vacuole: Tonoplast membrane; ATPases; transporters; as storage organelle.

Nucleus: Structure; nuclear pores; nucleosome organization; DNA structure; A, B and Z forms; replication, damage and repair; transcription; plant promoters and transcription factors; splicing; mRNA transport; nucleolous; rRNA biosynthesis.

Ribosomes: Structure; site of protein synthesis; mechanism of translation, initiation, elongation and termination; structure and role of tRNA.

Protein sorting: Targeting of proteins to organelles.

Cell shape and motility: The cytoskeleton; organization and role of microtubules and microfilaments; motor movements; implications in flagellar and other movements.

Cell cycle and apoptosis: Control mechanisms; role of cyclins and cyclin-dependent kinases; retinoblastoma and E2F proteins; cytokinesis and cell plate formation; mechanisms of programmed cell death.

Other cellular organelles: Structure and functions of microbodies, golgi apparatus, lysosomes, endoplasmic reticulum.

Techniques in cell biology: Immunotechniques; *in situ* hybridization to locate transcripts in cell types; FISH, GISH; confocal microscopy.

Suggested Readings

Lewin, B. 2000. Genes VII. Oxford University Press, New York.

Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K., and Watson, J.D. 1999. Molecular Biology of the Cell. Garland Publishing, Inc., New York.

Wolfe, S.L. 1993. Molecular and Cellular Biology. Wadsworth Publishing Co., California, USA.

Rost, T. et al. 1998. Plant Biology. Wadsworth Publishing Co., California, USA.

Krishnamurthy, K.V. 2000. Methods in Cell Wall Cytochemistry. CRC Press, Boca Raton, Florida.

Buchanan, B.B., Gruissem, W. and Jones, R.L. 2000. Biochemistry and Molecular Biology of Plants. American Society of Plant Physiologists, Maryland, USA

De, D.N. 2000. Plant Cell Vacuoles: An Introduction. CSIRO Publication, Collingwood, Australia.

Kleinsmith, L.J. and Kish, V.M. 1995. Principles of Cell and Molecular Biology (2nd Edition). Harper Collins College Publishers, New York, USA.

Lodish, H., Berk, A., Zipursky, S.L., Matsudaira, P., Baltimore, D. and Darnell, J. 2000. Molecular Cell Biology (4th Edition). W.H. Freeman and Co., New York, USA.

See the following Review Journals

Annual Review of Plant Physiology and Molecular Biology.

Current Advances in Plant Sciences.

Trends in Plant Sciences.

Nature Reviews: Molecular and Cell Biology.

Suggested Laboratory Exercises

1. Isolation of mitochondria and the activity of its marker enzyme, succinate dehydrogenase (SDH).
2. Isolation of chloroplasts and SDS-PAGE profile of proteins to demarcate the two subunits of Rubisco.
3. Isolation of nuclei and identification of histones by SDS-PAGE.
4. Isolation of plant DNA and its quantitation by a spectrophotometric method.
5. Isolation of DNA and preparation of '*cot*' curve.
6. Restriction digestion of plant DNA, its separation by agarose gel electrophoresis and visualization by ethidium bromide staining.
7. Isolation of RNA and quantitation by a spectrophotometric method.
8. Separation of plant RNA by agarose gel electrophoresis and visualization by EtBr staining.
9. Southern blot analysis using a gene specific probe.
10. Northern blot analysis using a gene specific probe.
11. Immunological techniques: Ouchterlony method, ELISA and western blotting.
12. Fluorescence staining with FDA for cell viability and cell wall staining with calcofluor.
13. Demonstration of SEM and TEM.

Note: Chemicals and kits for conducting some of the above molecular biology experiments are available in India, for example from M/s Bangalore Genei, and Centre for Biotechnology (CSIR), Mall Road, Delhi.

Suggested Readings (for laboratory exercises)

Glick, B.R. and Thompson, J.E. 1993. Methods in Plant Molecular Biology and Biotechnology. CRC Press, Boca Raton, Florida.

Glover, D.M. and Hames, B.D. (Eds), 1995. DNA Cloning 1: A Practical Approach; Core Techniques, 2nd edition. PAS, IRL Press at Oxford University Press, Oxford.

Gunning, B.E.S. and Steer, M.W. 1996. Plant Cell Biology: Structure and Function. Jones and Bartlett Publishers, Boston, Massachusetts.

Hackett, P.B., Fuchs, J.A. and Messing, J.W. 1988. An Introduction to Recombinant DNA Techniques: Basic Experiments in Gene Manipulation. The Benjamin/Cummings Publishing Co., Inc Menlo Park, California.

Hall, J.L. and Moore, A.L. 1983. Isolation of Membranes and Organelles from Plant Cells. Academic Press, London, UK.

Harris, N. and Oparka, K.J. 1994. Plant Cell Biology: A Practical Approach. IRL Press, at Oxford University Press, Oxford, U.K.

Shaw, C.H. (Ed.), 1988. Plant Molecular Biology: A Practical Approach. IRL Press, Oxford.

COURSE II. CYTOLOGY, GENETICS AND CYTOGENETICS

CYTOLOGY

Chromatin organization: Chromosome structure and packaging of DNA, molecular organization of centromere and telomere; nucleolus and ribosomal RNA genes; euchromatin and heterochromatin; karyotype analysis; banding patterns; karyotype evolution; specialized types of chromosomes; polytene, lampbrush, B-chromosomes and sex chromosomes; molecular basis of chromosome pairing.

Structural and numerical alterations in chromosomes: Origin, meiosis and breeding behaviour of duplication, deficiency, inversion and translocation heterozygotes; origin, occurrence, production and meiosis of haploids, aneuploids and euploids; origin and production of autopolyploids; chromosome and chromatid segregation; allopolyploids, types, genome constitution and analysis; evolution of major crop plants; induction and characterization of trisomics and monosomics.

GENETICS

Genetics of prokaryotes and eukaryotic organelles: Mapping the bacteriophage genome; phage phenotypes; genetic recombination in phage; genetic transformation, conjugation and transduction in bacteria; genetics of mitochondria and chloroplasts; cytoplasmic male sterility.

Gene structure and expression: Genetic fine structure; cis-trans test; fine structure analysis of eukaryotes; introns and their significance; RNA splicing; regulation of gene expression in prokaryotes and eukaryotes.

Genetic recombination and genetic mapping: Recombination; independent assortment and crossing over; molecular mechanism of recombination; role of RecA and RecBCD enzymes; site-specific recombination; chromosome mapping, linkage groups, genetic markers, construction of molecular maps, correlation of genetic and physical maps; somatic cell genetics – an alternative approach to gene mapping.

Mutations: Spontaneous and induced mutations; physical and chemical mutagens; molecular basis of gene mutations; transposable elements in prokaryotes and eukaryotes; mutations induced by transposons; site-directed mutagenesis; DNA damage and repair mechanisms; inherited human diseases and defects in DNA repair; initiation of cancer at cellular level; protooncogenes and oncogenes.

CYTOGENETICS

Cytogenetics of aneuploids and structural heterozygotes: Effect of aneuploidy on phenotype in plants; transmission of monosomics and trisomics and their use in chromosome mapping of diploid and polyploid species; breeding behaviour and genetics of structural heterozygotes; complex translocation heterozygotes; translocation tester sets; Robertsonian translocations; B-A translocations.

Molecular cytogenetics: Nuclear DNA content; C-value paradox; *cot* curve and its significance; restriction mapping - concept and techniques; multigene families and their evolution; *in situ* hybridization - concept and techniques; physical mapping of genes on chromosomes; computer assisted chromosome analysis; chromosome microdissection and microcloning; flow cytometry and confocal microscopy in karyotype analysis.

Alien gene transfer through chromosome manipulations: Transfer of whole genome, examples from wheat, *Arachis* and *Brassica;* transfer of individual chromosomes and chromosome segments; methods for detecting alien chromatin; production, characterization and utility of alien addition and substitution lines; genetic basis of inbreeding and heterosis; exploitation of hybrid vigour.

Suggested Readings

Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K. and Watson, J.D. 1989. Molecular Biology of the Cell (2nd edition). Garland Publishing Inc., New York.

Atherly, A.G., Girton, J.R. and McDonald, J.F. 1999. The Science of Genetics. Saunders College Publishing, Fort Worth, USA.

Burnham, C.R. 1962. Discussions in Cytogenetics. Burgess Publishing Co., Minnesota.

Busch, H. and Rothblum, L. 1982. Volume X. The Cell Nucleus rDNA Part A. Academic Press.

Hartl, D.L. and Jones, E.W. 1998. Genetics: Principles and Analysis (4th edition). Jones & Bartlett Publishers, Massachusetts, USA.

Khush, G.S. 1973. Cytogenetics of Aneuploids. Academic Press, New York, London.

Karp, G. 1999. Cells and Molecular Biology: Concepts and Experiments. John Wiley & Sons, Inc., U.S.A.

Lewin, B. 2000. Gene VII. Oxford University Press, New York, USA.

Lewis, R. 1997. Human Genetics: Concepts and Applications (2nd edition). WCB McGraw Hill, USA.

Malacinski, G.M. and Freifelder, D. 1998. Essentials of Molecular Biology (3d edition). Jones and Bartlet Publishers, Inc., London.

Russel, P. J. 1998. Genetics (5th edition). The Benjamin/Cummings Publishing Company Inc., USA.

Snustad, D.P. and Simmons, M.J. 2000. Principles of Genetics (2nd edition). John Wiley & Sons Inc., USA.

Suggested Laboratory Exercises

Linear differentiation of chromosomes through banding techniques, such as G-banding, C-banding and Q-banding.

Silver banding for staining nucleolus-organizing region, where 18S and 28S rDNA are transcribed.

Orcein and Feulgen staining of the salivary gland chromosomes of *Chironomas* and *Drosophila.*

Characteristics and behaviour of B chromosomes using maize or any other appropriate material.

Working out the effect of mono- and tri-somy on plant phenotype, fertility and meiotic behaviour.

Induction of polyploidy using colchicine; different methods of the application of colchicine.

Effect of induced and spontaneous polyploidy on plant phenotype, meiosis, pollen and seed fertility and fruit set.

Effect of translocation heterozygosity on plant phenotype, chromosome pairing and chromosome disjunction and pollen and seed fertility.

Meiosis of complex translocation heterozygotes.

Isolation of chlorophyll mutants following irradiation and treatment with chemical mutagens.

Estimation of nuclear DNA content through microdensitometry and flow cytometry.

Fractionation and estimation of repetitive and unique DNA sequences in nuclear DNA.

Suggested Readings (for laboratory exercises)

Fukui, K. and Nakayama, S. 1996. Plant Chromosomes: Laboratory Methods. CRC Press, Boca Raton, Florida.

Sharma, A.K. and Sharma, A. 1999. Plant Chromosomes: Analysis, Manipulation and Engineering. Harwood Academic Publishers, Australia.

COURSE III. BIOLOGY AND DIVERSITY OF LOWER PLANTS: CRYPTOGAMS

MICROBIOLOGY

a. Archaebacteria and eubacteria: General account; ultrastructure, nutrition and reproduction; biology and economic importance; cyanobacteria – salient features and biological importance.

b. Viruses : Characteristics and ultrastructure of virions; isolation and purification of viruses; chemical nature, replication, transmission of viruses; economic importance.

c. Phytoplasma : General characteristics and role in causing plant diseases.

Phycology: Algae in diversified habitats (terrestrial, freshwater, marine); thallus organization; cell ultrastructure; reproduction (vegetative, asexual, sexual); criteria for classification of algae: pigments, reserve food, flagella; classification, salient features of Protochlorophyta, Chlorophyta, Charophyta, Xanthophyta, Bacillariophyta, Phaeophyta and Rhodophyta; algal blooms, algal biofertilizers; algae as food, feed and uses in industry.

Mycology: General characters of fungi; substrate relationship in fungi; cell ultrastructure; unicellular and multicellular organization; cell wall composition; nutrition (saprobic, biotrophic, symbiotic); reproduction (vegetative, asexual, sexual); heterothallism; heterokaryosis; parasexuality; recent trends in classification.

Phylogeny of fungi; general account of Mastigomycotina, Zygomycotina, Ascomycotina, Basidiomycotina, Deuteromycotina; fungi in industry, medicine and as food; fungal diseases in plants and humans; Mycorrhizae; fungi as biocontrol agents.

Bryophyta: Morphology, structure, reproduction and life history; distribution; classification; general account of Marchantiales, Junger-maniales, Anthoceratales, Sphagnales, Funariales and Polytrichales; economic and ecological importance.

Pteridophyta: Morphology, anatomy and reproduction; classification; evolution of stele; heterospory and origin of seed habit; general account of fossil pteriodophyta; introduction to Psilopsida, Lycopsida, Sphenopsida and Pteropsida.

Suggested Readings

Alexopoulus, C.J., Mims, C.W. and Blackwel, M. 1996. Introductory Mycology. John Wiley & Sons Inc.

Clifton, A. 1958. Introduction to the Bacteria. McGraw-Hill Book Co., New York.

Kumar, H.D. 1988. Introductory Phycology. Affiliated East-West Press Ltd., New Delh.

Mandahar, C.L. 1978. Introduction to Plant Viruses. Chand & Co. Ltd., Delhi.

Mehrotra, R.S. and Aneja, R.S. 1998. An Introduction to Mycology. New Age Intermediate Press.

Morris, I. 1986. An Introduction to the Algae. Cambridge University Press, U.K.

Parihar, N.S. 1991. Bryophyta. Central Book Depot, Allahabad.

Parihar, N.S. 1996. Biology & Morphology of Pteridophytes. Central Book Depot, Allahabad.

Puri, P. 1980. Bryophytes. Atma Ram & Sons, Delhi.

Rangaswamy, G. and Mahadevan, A. 1999. Diseases of Crop Plants in India (4^{h} edition). Prentice Hall of India Pvt. Ltd., New Delhi.

Round, F.E. 1986. The Biology of Algae. Cambridge University Press, Cambridge.

Sporne, K.K. 1991. The Morphology of Pteridophytes. B.I. Publishing Pvt. Ltd., Bombay.

Stewart, W.N. and Rathwell, G.W. 1993. Paleobotany and the Evolution of Plants. Cambridge University Press.

Webster, J. 1985. Introduction to Fungi. Cambridge University Press.

Suggested Laboratory Exercises

Morphological study of representative members of algae, fungi, bacteria, bryophytes and pteridophytes: *Microcystis, Aulosira, Oocystis, Pediastrum, Hydrodictyon, Ulva, Pithophora, Stigeoclonium, Drapranaldiopsis. Closterium, Cosmarium, Chara, Stemonitis, Peronospora, Albugo, Mucor, Pilobolus, yeast, Emericella, Chaetomium, Pleospora, Morchella, Melampspora, Phallus. Polyporus, Drechslera, Phoma, Penicillium, Aspergillus, Colletotrichum, Marchantia, Anthoceros, Polytrichum, Psilotum, Lycopodium, Selaginella, Equisetum, Gleichenia, Pteris, Ophioglossum, Isoetes.*

Symptomology of some diseased specimens: White rust, downy mildew, powdery mildew, rusts, smuts, ergot, groundnut leaf spot, red rot of sugarcane, wilts, paddy blast, citrus canker, bacterial blight of paddy, angular leaf spot of cotton, tobacco mosaic, little leaf of brinjal, seasame phyllody, mango malformation.

Study of morphology, anatomy and reproductive structures of bryophytes and pteridophytes.

Gram staining of bacteria.

Identification of fungal cultures: *Rhizopus, Mucor, Aspergillus, Penicillium, Emericella, Chaetomium, Drechslera, Curvularia, Fusarium, Phoma, Colletotrichum, Graphium.*

Sterilization methods, preparation of media and stains.

COURSE IV. TAXONOMY AND DIVERSITY OF SEED PLANTS

GYMNOSPERMS

Introduction: Gymnosperms, the vessel-less and fruitless seed plants varying in the structure of their sperms, pollen grains, pollen germination and the complexity of their female gametophyte; evolution of gymnosperms.

Classification of Gymnosperms and their Distribution in India.

Brief account of the families of Pteridospermales (Lyginopteridaceae, Medullosaceae, Caytoniaceae and Glossopteridaceae).

General Account of Cycadeoidales and Cordaitales

Structure and reproduction in Cycadales, Ginkgoales, Coniferales, Ephedrales, Welwitschiales and Gnetales.

TAXONOMY OF ANGIOSPERMS

Origin of intrapopulation variation: Population and the environment; ecads and ecotypes; evolution and differentiation of species – various models.

The species concept: Taxonomic hierarchy, species, genus, family and other categories; principles used in assessing relationship, delimitation of taxa and attribution of rank.

Salient features of the International Code of Botanical nomenclature.

Taxonomic evidence: Morphology, anatomy, palynology, embryology, cytology; phytochemistry; genome analysis and nucleic acid hybridization.

Taxonomic tools: Herbarium; floras; histological, cytological, phytochemical, serological, biochemical and molecular techniques; computers and GIS.

Systems of angiosperm classification: Phenetic versus phylogenetic systems; cladistics in taxonomy; relative merits and demerits of major systems of classification; relevance of taxonomy to conservation, sustainable utilization of bio-resources and ecosystem research.

Concepts of phytogeography: Endemism, hotspots and hottest hotspots; plant explorations; invasions and introductions; local plant diversity and its socio-economic importance.

Suggested Readings

Bhatnagar, S.P. and Moitra, A. 1996. Gymnosperms. New Age International Pvt. Ltd., New Delhi.

Cole, A.J. 1969. Numerical Taxonomy, Academic Press, London.

Davis, P.H. and Heywood, V.H. 1973. Principles of Angiosperms Taxonomy. Robert E. Kreiger Pub. Co., New York.

Grant, V. 1971. Plant Speciation. Columbia University Press, New York.

Grant, W.F. 1984. Plant Biosystematics. Academic Press, London.

Harrison, H.J. 1971. New Concepts in Flowering Plant Taxonomy. Hieman Educational Books Ltd., London.

Heslop-Harrison, J. 1967. Plant Taxonomy. English Language Book Soc. & Edward Arnold Pub. Ltd., UK.

Heywood, V.H. and Moore, D.M. 1984. Current Concepts in Plant Taxonomy. Academic Press, London.

Jones, A.D. and Wilbins, A.D. 1971. Variations and Adaptations in Plant Species. Hieman & Co. Educational Books Ltd., London.

Jones, S.B., Jr. and Luchsinger, A.E. 1986. Plant Systematics (2nd edition). McGraw-Hill Book Co., New York.

Nordenstam, B., El Gazaly, G. and Kassas, M. 2000. Plant Systematics for 21st Century. Portlant Press Ltd., London.

Radford, A.E. 1986. Fundamentals of Plant Systematics. Harper & Row Publications, USA.

Singh, H. 1978. Embryology of Gymnosperms. Encyclopaedia of Plant Anatomy X. Gebruder Bortraeger, Berlin.

Solbrig, O.T. 1970. Principles and Methods of Plant Biosystematics. The MacMillan Co.– Collier-MacMillan Ltd., London.

Solbrig, O.T. and Solbrig, D.J. 1979. Population Biology and Evolution. Addison-Wesley Publicating Co. Inc., USA.

Stebbins, G.L. 1974. Flowering Plant– Evolution Above Species Level. Edward Arnold Ltd., London.

Stace, C.A. 1989. Plant Taxonomy and Biosystematics (2nd edition). Edward Arnold Ltd., London.

Takhtajan, A.L. 1997. Diversity and Classification of Flowering Plants. Columbia University Press, New York.

Woodland, D.W. 1991. Contemporary Plant Systematics. Prentice Hall, New Jersey.

Suggested Laboratory Exercises

Gymnosperms

1. Comparative study of the anatomy of vegetative and reproductive parts of *Cycas*, *Ginkgo*, *Cedrus*, *Abies*, *Picea*, *Cupressus*, *Araucaria*, *Cryptomeria*, *Taxodium*, *Podocarpus*, *Agathis*, *Taxus*, *Ephedra* and *Gnetum*.
2. Study of important fossil gymnosperms from prepared slides and specimens.

Angiosperms

3. Description of a specimen from representative, locally available families.
4. Description of a species based on various specimens to study intraspecific variation: a collective exercise.
5. Description of various species of a genus; location of key characters and preparation of keys at generic level.
6. Location of key characters and use of keys at family level.
7. Field trips within and around the campus; compilation of field notes and preparation of herbarium sheets of such plants, wild or cultivated, as are abundant.
8. Training in using floras and herbaria for identification of specimens described in the class.
9. Demonstration of the utility of secondary metabolites in the taxonomy of some appropriate genera.
10. Comparison of different species of a genus and different genera of a family to calculate similarity coefficients and preparation of dendrograms.

COURSE V. PLANT PHYSIOLOGY AND METABOLISM

Energy flow: Principles of thermodynamics, free energy and chemical potential, redox reactions, structure and functions of ATP.

Fundamentals of enzymology: General aspects, allosteric mechanism, regulatory and active sites, isozymes, kinetics of enzymatic catalysis, Michaelis-Menten equation and its significance.

Membrane transport and translocation of water and solutes: Plant-water relations, mechanism of water transport through xylem, root-microbe interactions in facilitating nutrient uptake, comparison of xylem and phloem transport, phloem loading and unloading, passive and active solute transport, membrane transport proteins.

Signal transduction: Overview, receptors and G-proteins, phospholipid signaling, role of cyclic nucleotides, calcium-calmodulin cascade, diversity in protein kinases and phosphatases, specific signaling mechanisms, e.g. two-component sensor-regulator system in bacteria and plants, sucrose-sensing mechanism.

Photochemistry and photosynthesis: General concepts and historical background, evolution of photosynthetic apparatus, photosynthetic pigments and light harvesting complexes, photooxidation of water, mechanisms of electron and proton transport, carbon assimilation – the Calvin cycle, photorespiration and its significance, the C_4 cycle, the CAM pathway, biosynthesis of starch and sucrose, physiological and ecological considerations.

Respiration and lipid metabolism: Overview of plant respiration, glycolysis, the TCA cycle, electron transport and ATP synthesis, pentose phosphate pathway, glyoxylate cycle, alternative oxidase system, structure and function of lipids, fatty acid biosynthesis, synthesis of membrane lipids, structural lipids and storage lipids, and their catabolism.

Nitrogen fixation, nitrogen and sulphur metabolism: Overview, biological nitrogen fixation, nodule formation and nod factors, mechanism of nitrate uptake and reduction, ammonium assimilation, sulfate uptake, transport and assimilation.

Sensory photobiology: History of discovery of phytochromes and cryptochromes, and their photochemical and biochemical properties, photophysiology of light-induced responses, cellular localization, molecular mechanism of action of photomorphogenic receptors, signaling and gene expression.

Plant growth regulators and elicitors: Physiological effects and mechanism of action of auxins, gibberellins, cytokinins, ethylene, abscisic acid, brassinosteroids, polyamines, jasmonic acid and salicylic acid, hormone receptors, signal transduction and gene expression.

The flowering process: Photoperiodism and its significance, endogenous clock and its regulation, floral induction and development - genetic and molecular analysis, role of vernalization.

Stress physiology: Plant responses to biotic and abiotic stress, mechanisms of biotic and abiotic stress tolerance, HR and SAR, water deficit and drought resistance, salinity stress, metal toxicity, freezing and heat stress, oxidative stress.

Suggested Readings

Buchanan, B.B., Gruissem, W. and Jones, R.L. 2000. Biochemistry and Molecular Biology of Plants. American Society of Plant Physiologists, Maryland, USA.

Dennis, D.T., Turpin, D.H., Lefebvre, D.D. and Layzell, D.B. (eds) 1997. Plant Metabolism (second edition). Longman, Essex, England.

Galston, A.W. 1989. Life Processes in Plants. Scientific American Library, Springer-Verlag, New York, USA.

Hooykaas, P.J.J., Hall, M.A. and Libbenga, K.R. (eds) 1999. Biochemistry and Molecular Biology of Plant Hormones. Elsevier, Amsterdam, The Netherlands.

Hopkins, W.G. 1995. Introduction to Plant Physiology. John Wiley & Sons, Inc., New York, USA.

Lodish, H., Berk, A., Zipursky, S.L., Matsudaira, P., Baltimore, D. and Darnell, J. 2000. Molecular Cell Biology (fourth edition). W.H. Freeman and Company, New York, USA.

Moore, T.C. 1989. Biochemistry and Physiology of Plant Hormones (second edition). Springer-Verlag, New York, USA.

Nobel, P.S. 1999. Physiochemical and Environmental Plant Physiology (second edition). Academic Press, San Diego, USA.

Salisbury, F.B. and Ross, C.W. 1992. Plant Physiology (4^{th} edition). Wadsworth Publishing Co., California, USA.

Singhal, G.S., Renger, G., Sopory, S.K., Irrgang, K.-D. and Govindjee 1999. Concepts in Photobiology: Photosynthesis and Photomorphogenesis. Narosa Publishing House, New Delhi.

Taiz, L. and Zeiger, E. 1998. Plant Physiology (2^{nd} edition). Sinauer Associates, Inc., Publishers, Massachusetts, USA.

Thomas, B. and Vince-Prue, D. (1997) Photoperiodism in Plants (second edition). Academic Press, San Diego, USA.

Westhoff, P. (1998) Molecular Plant Development: from Gene to Plant. Oxford University Press, Oxford, UK.

Suggested Laboratory Exercises

1. Effect of time and enzyme concentration on the rate of reaction of enzyme (e.g. acid phosphatase, nitrate reductase).
2. Effect of substrate concentration on activity of any enzyme and determination of its Km value.
3. Demonstration of the substrate inducibility of the enzyme nitrate reductase.
4. Extraction of chloroplast pigments from leaves and preparation of the absorption spectrum of chlorophylls and carotenoids.
5. To determine the chlorophyll *a*/chlorophyll *b* ratio in C3 and C4 plants.

6. Isolation of intact chloroplasts and estimation of chloroplast proteins by spot protein assay.
7. To demonstrate photophosphorylation in intact chloroplasts, resolve the phosphoproteins by SDS-PAGE and perform autoradiography.
8. Extraction of seed proteins depending upon the solubility.
9. Determination of succinate dehydrogenase activity, its kinetics, and sensitivity to inhibitors.
10. Desalting of proteins by gel filtration chromatography employing Sephadex G25.
11. Preparation of the standard curve of protein (BSA) and estimation of the protein content in extracts of plant material by Lowry's or Bradford's method.
12. Fractionation of proteins using gel filtration chromatography by Sephadex G100 or Sephadex G200.
13. SDS-PAGE for soluble proteins extracted from the given plant materials and comparison of their profile by staining with Coomassie Brilliant Blue or silver nitrate.
14. Separation of isozymes of esterases, peroxidases by native polyacrylamide gel electrophoresis.
15. Radioisotope methodology, autoradiography, instrumentation (GM counter and Scintillation counter) and principles involved.
16. Principles of colorimetry, spectrophotometry and fluorimetry.

Suggested Readings (for laboratory exercises)

Bajracharya, D. 1999. Experiments in Plant Physiology: A Laboratory Manual. Narosa Publishing House, New Delhi.

Çooper, T.G. 1977. Tools in Biochemistry. John Wiley, New York, USA.

Copeland, R.A. 1996. Enzymes: A Practical Introduction to Structure, Mechanism, and Data Analysis. VCH Publishers, New York.

Dennison, C. 1999. A Guide to Protein Isolation. Kluwer Academic Publishers, Dordrecht, The Netherland.

Devi, P. 2000. Principles and Methods of Plant Molecular Biology, Biochemistry and Genetics. Agrobios, Jodhpur, India.

Dryer, R.L. and Lata, G.F. 1989. Experimental Biochemistry. Oxford University Press, New York.

Hames, B.D. (Ed.) 1998. Gel Electrophoresis of Proteins: A Practical Approach, 3rd edition. PAS, Oxford University Press, Oxford, U.K.

Harborne, T.C. (1981) Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis. Chapman & Hall, London.

Moore, T.C. 1974. Research Experiences in Plant Physiology: A Laboratory Manual. Springer-Verlag, Berlin.

Ninfa, A.J. and Ballou, D.P. 1998. Fundamental Laboratory Approaches for Biochemistry and Biotechnology. Fitzgerald Science Press, Inc., Maryland, USA.

Plummer, D.T. 1988. An Introduction to Practical Biochemistry. Tata McGraw-Hill Publishing Co. Ltd., New Delhi.

Scott, R.P.W. 1995. Techniques and Practice of Chromatography. Marcel Dekker, Inc., New York.

Wilson, K. and Goulding, K.H. (Eds), 1986. A Biologists Guide to Principles and Techniques of Practical Biochemistry. Edward Arnold, London, UK.

Wilson, K. and Walker, J. 1994. Practical Biochemistry: Principles and Techniques, 4th edition. Cambridge University Press, Cambridge, UK.

COURSE VI. PLANT DEVELOPMENT AND REPRODUCTION

Introduction: Unique features of plant development; differences between animal and plant development.

Seed germination and seedling growth: Metabolism of nucleic acids, proteins and mobilization of food reserves; tropisms; hormonal control of seedling growth; gene expression; use of mutants in understanding seedling development.

Shoot development: Organization of the shoot apical meristem (SAM); cytological and molecular analysis of SAM; control of cell division and cell to cell communication; control of tissue differentiation, especially xylem and phloem; secretory ducts and laticifers; wood development in relation to environmental factors.

Leaf growth and differentiation: Determination; phyllotaxy; control of leaf form; differentiation of epidermis (with special reference to stomata and trichomes) and mesophyll.

Root development: Organization of root apical meristem (RAM); cell fates and lineages; vascular tissue differentiation; lateral roots; root hairs; root-microbe interactions.

Reproduction: Vegetative options and sexual reproduction; flower development; genetics of floral organ differentiation; homeotic mutants in *Arabidopsis* and *Antirrhinum*; sex determination.

Male gametophyte: Structure of anthers; microsporogenesis, role of tapetum; pollen development and gene expression; male sterility; sperm dimorphism and hybrid seed production; pollen germination, pollen tube growth and guidance; pollen storage; pollen allergy; pollen embryos.

Female gametophyte: Ovule development; megasporogenesis; organization of the embryo sac, structure of the embryo sac cells.

Pollination, pollen-pistil interaction and fertilization: Floral characteristics, pollination mechanisms and vectors; breeding systems; commercial considerations; structure of the pistil; pollen-stigma interactions, sporophytic and gametophytic self-incompatibility (cytological, biochemical and molecular aspects); double fertilization; in vitro fertilization.

Seed development and fruit growth: Endosperm development during early, maturation and desiccation stages; embryogenesis, ultrastructure and nuclear cytology; cell lineages during late embryo development; storage proteins of endosperm and embryo; polyembryony; apomixis; embryo culture; dynamics of fruit growth; biochemistry and molecular biology of fruit maturation.

Latent life - dormancy: Importance and types of dormancy; seed dormancy; overcoming seed dormancy; bud dormancy.

Senescence and programmed cell death (PCD): Basic concepts, types of cell death, PCD in the life cycle of plants, metabolic changes associated with senescence and its regulation; influence of hormones and environmental factors on senescence.

Suggested Readings

Atwell, B.J., Kriedermann, P.E. and Jurnbull, C.G.N. (eds) 1999. Plants in Action: Adaptation in Nature, Performance in Cultivation. MacMillan Education, Sydney, Australia.

Bewley, J.D. and Black, M. 1994. Seeds: Physiology of Development and Germination. Plenum Press, New York.

Bhojwani, S.S. and Bhatnagar, S.P. 2000. The Embryology of Angiosperms (4th revised and enlarged edition). Vikas Publishing House, New Delhi.

Burgess, J. 1985. An Introduction to Plant Cell Development. Cambridge University Press, Cambridge.

Fageri, K. and Van der Pijl, L. 1979. The Principles of Pollination Ecology. Pergamon Press, Oxford.

Fahn, A. 1982. Plant Anatomy. (3rd edition). Pergamon Press, Oxford.

Fosket, D.E. 1994. Plant Growth and Development. A Molecular Approach. Academic Press, San Diego.

Howell, S.H. 1998. Molecular Genetics of Plant Development. Cambridge University Press, Cambridge.

Leins, P., Tucker, S.C. and Endress, P.K. 1988. Aspects of Floral Development. J. Cramer, Germany.

Lyndon, R.F. 1990. Plant Development. The Cellular Basis. Unnin Hyman, London.

Murphy, T.M. and Thompson, W.F. 1988. Molecular Plant Development. Prentice Hall, New Jersey.

Proctor, M. and Yeo, P. 1973. The Pollination of Flowers. William Collins Sons, London.

Raghavan, V. 1997. Molecular Embryology of Flowering Plants. Cambridge University Press, Cambridge.

Raghavan, V. 1999. Developmental Biology of Flowering Plants. Springer-Verlag, New York.

Raven, P.H., Evert, R.F. and Eichhorn, S.E. 1992. Biology of Plants (5th edition). Worth, New York.

Salisbury, F.B. and Ross, C.W. 1992. Plant Physiology (4th edition). Wadsworth Publishing, Belmont, California.

Steeves, T.A. and Sussex, I.M. 1989. Patterns in Plant Development (2nd edition). Cambridge University Press, Cambridge.

Sedgely, M. and Griffin, A.R. 1989. Sexual Reproduction of Tree Crops. Academic Press, London.

Waisel, Y., Eshel, A. and Kafkaki, U. (eds) 1996. Plant Roots: The Hidden Hall (2nd edition). Marcel Dekker, New York.

Shivanna, K.R. and Sawhney, V.K. (eds) 1997. Pollen Biotechnology for Crop Production and Improvement. Cambridge University Press, Cambridge.

Shivanna, K.R. and Rangaswamy, N.S. 1992. Pollen Biology: A Laboratory Manual. Springer-Verlag, Berlin.

Shivanna, K.R. and Johri, B.M. 1985. The Angiosperm Pollen: Structure and Function. Wiley Eastern Ltd., New York.

The Plant Cell. Special Issue on Reproductive Biology of Plants, Vol. 5(10) 1993. The American Society of Plant Physiologists, Rockville, Maryland, USA.

Suggested Laboratory/Field Excercises

1. Effect of gravity, unilateral light and plant growth regulators on the growth of young seedlings.
2. Role of dark and red light/far-red light on the expansion of cotyledons and epicotylar hook opening in pea.

3. Study of living shoot apices by dissections using aquatic plants such as *Ceratophyllum* and *Hydrilla.*
4. Study of cytohistological zonation in the shoot apical meristem (SAM) in sectioned and double-stained permanent slides of a suitable plant such as *Coleus, Kalanchoe,* tobacco. Examination of shoot apices in a monocotyledon in both T.S. and L.S. to show the origin and arrangement of leaf primordia.
5. Study of alternate and distichous, alternate and superposed, opposite and superposed; opposite and decussate leaf arrangement. Examination of rosette plants (*Launaea, Mollugo, Raphanus, Hyoscyamus* etc) and induction of bolting under natural conditions as well as by GA treatment.
6. Microscopic examination of vertical sections of leaves such as *Cannabis*, tobacco, *Nerium*, maize and wheat to understand the internal structure of leaf tissues and trichomes, glands etc. Also study the C3 and C4 leaf anatomy of plants.
7. Study of epidermal peels of leaves such as *Coccinia*, *Gaillardia*, *Tradescantia*, *Notonea*, etc. to study the development and final structure of stomata and prepare stomatal index. Demonstration of the effect of ABA on stomatal closure.
8. Study of whole roots in monocots and dicots. Examination of L.S. of root from a permanent preparation to understand the organization of root apical meristem and its derivatives. (use maize, aerial roots of banyan, *Pistia*, *Jussieua* etc.) Origin of lateral roots. Study of leguminous roots with different types of nodules.
9. Study of microsporogenesis and gametogenesis in sections of anthers.
10. Examination of modes of anther dehiscence and collection of pollen grains for microscopic examination (maize, grasses, *Cannabis sativa*, *Crotolaria*, *Tradescantia*, *Brassica*, *Petunia*, *Solanum melongena*, etc.).
11. Tests for pollen viability using stains and *in vitro* germination. Pollen germination using hanging drop and sitting drop cultures, suspension culture and surface culture.
12. Estimating percentage and average pollen tube length *in vitro.*
13. Role of transcription and translation inhibitors on pollen germination and pollen tube growth.
14. Pollen storage, pollen-pistil interaction, self-incompatibility, *in vitro* pollination.
15. Study of ovules in cleared preparations; study of monosporic, bisporic and tetrasporic types of embryo sac development thorough examination of permanent, stained serial sections.
16. Field study of several types of flower with different pollination mechanisms (wind pollination, thrips pollination, bee/butterfly pollination, bird pollination).

17. Emasculation, bagging and hand pollination to study pollen germination, seed set and fruit development using self compatible and obligate outcrossing systems. Study of cleistogamous flowers and their adaptations.
18. Study of nuclear and cellular endosperm through dissections and staining.
19. Isolation of zygotic globular, heart-shaped, torpedo stage and mature embryos from suitable seeds and polyembryony in citrus, jamun (*Syzygium cumini*) etc. by dissections.
20. Study of seed dormancy and methods to break dormancy.

Suggested Readings (for Laboratory Exercises)

Shivanna, K.R. and Rangaswamy, N.S. 1992. Pollen Biology: A Laboraotry Mannual. Springer-Verlag, Berlin-Heidelberg (and references therein).

Chopra V.L. 2001. Plant Breeding: Theory and Practice. Oxford IBH Pvt. Ltd., New Delhi.

Chopra V.L. 2001. Plant Breeding: Field Crops. Oxford IBH Pvt. Ltd., New Delhi.

COURSE VII. PLANT ECOLOGY

Climate, soil and vegetation patterns of the world: Life zones; major biomes and major vegetation and soil types of the world.

Vegetation organization: Concepts of community and continuum; analysis of communities (analytical and synthetic characters); community coefficients; interspecific associations, ordination; concept of ecological niche.

Vegetation development: Temporal changes (cyclic and non-cyclic); mechanism of ecological succession (relay floristics and initial floristic composition; facilitation, tolerance and inhibition models); changes in ecosystem properties during succession.

Ecosystem organization: Structure and functions; primary production (methods of measurement, global pattern, controlling factors); energy dynamics (trophic organization, energy flow pathways, ecological efficiencies); litter fall and decomposition (mechanism, substrate quality and climatic factors); global biogeochemical cycles of C, N, P and S; mineral cycles (pathways, processes, budgets) in terrestrial and aquatic ecosystems.

Biological diversity: Concept and levels; role of biodiversity in ecosystem functions and stability; speciation and extinction; IUCN categories of threat; distribution and global patterns; terrestrial biodiversity hot spots; inventory.

Air, water and soil pollution: Kinds; sources; quality parameters; effects on plants and ecosystems.

Climate change: Greenhouse gases (CO_2, CH_4, N_2O, CFCs: sources, trends and role); ozone layer and ozone hole; consequences of climate change (CO_2 fertilization, global warming, sea level rise, UV radiation).

Ecosystem stability: Concept (resistance and resilence); ecological perturbations (natural and anthropogenic) and their impact on plants and ecosystems; ecology of plant invasion; environmental impact assessment; ecosystem restoration.

Ecological management: Concepts; sustainable development; sustainability indicators.

Suggested Readings

Smith, R.L. 1996. Ecology and Field Biology. Harper Collins, New York.

Muller-Dombois, D. and Ellenberg, H. 1974. Aims and Methods of Vegetation Ecology, Wiley, New York.

Begon, M., Harper, J.L. and Townsend, C.R. 1996. Ecology. Blackwell Science, Cambridge, U.S.A.

Ludwig, J. and Reynolds, J.F. 1988. Statistical Ecology. John Wiley & Sons.

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Kormondy, E.J. 1996. Concepts of Ecology. Prentice-Hall of India Pvt. Ltd., New Delhi.

Chapman, J.L. and Reiss, M.J. 1988. Ecology: Principles and Applications. Cambridge University Press, Cambridge, U.K.

Moldan, B. and Billharz, S. 1997. Sustainability Indicators. John Wiley & Sons, New York.

Treshow, M. 1985. Air Pollution and Plant Life. Wiley Interscience.

Heywood, V.H. and Watson, R.T. 1995. Global Biodiversity Assessment. Cambridge University Press.

Mason, C.F. 1991. Biology of Freshwater Pollution. Longman.

Hill, M.K. 1997. Understanding Environmental Pollution. Cambridge University Press.

Brady, N.C. 1990. The Nature and Properties of Soils. MacMillan.

Suggested Laboratory Exercises

1. To calculate mean, variance, standard deviation, standard error, coefficient of variation and to use t-test for comparing two means related to ecological data.
2. To prepare ombrothermic diagram for different sites on the basis of given data set and to comment on climate.
3. To find out the relationship between two ecological variables using correlation and regression analysis.
4. To determine minimum size and number of quadrats required for reliable estimate of biomass in grasslands.
5. To find out association between important grassland species using Chi-square test.
6. To compare protected and unprotected grassland stands using community coefficients (similarity indices).
7. To analyse plant communities using Bra-Curtis ordination method.
8. To determine diversity indices (Shannon-Wiener, concentration of dominance, species richness, equitability and B-diversity) for protected and unprotected grassland stands.
9. To estimate IVI of the species in a woodland using point centred quarter method.
10. To determine gross and net phytoplankton productivity by light and dark bottle method.
11. To determine soil moisture content, porosity and bulk density of soils collected from varying depths at different locations.
12. To determine the water holding capacity of soils collected from different locations.
13. To determine percent organic carbon and organic matter in the soils of cropland, grassland and forest.
14. To estimate the dissolved oxygen content in eutrophic and oligotrophic water samples by azide modification of Winkler's method.
15. To estimate chlorophyll content in SO_2 fumigated and unfumigated plant leaves.

16. To estimate rate of carbon dioxide evolution from different soils using soda lime or alkali absorption method.
17. To study environmental impact of a given developmental activity using checklist as a EIA method.

Suggested Readings (for laboratory exercises)

Krebs, C.J. 1989. Ecological Methodology. Harper and Row, New York, USA.

Ludwig, J.A. and Reynolds, J.F. 1988. Statistical Ecology. Wiley, New York.

Magurran, A.E. 1988. Ecological Diversity and its Measurement. Chapman & Hall, London.

Pielou, E.C. 1984. The Interpretation of Ecological Data. Wiley, New York.

Sokal, R.R. and Rohlf, F.J. 1995. Biometry. W.H. Freeman & Co., San Francisco.

Moore, P.W. and Chapman, S.B. 1986. Methods in Plant Ecology. Blackwell Scientific Publications.

Misra, R. 1968. Ecology Work Book. Oxford & IBH, New Delhi.

APHA – Standard Methods for the Examination of Water and Waste Water. American Public Health Association, Washington, DC.

Smith, R.L. 1996. Ecology and Field Biology. Harper Collins, New York.

Muller-Dombois, D. and Ellenberg, H. 1974. Aims and Methods of Vegetation Ecology, Wiley, New York.

COURSE VIII. PLANT RESOURCE UTILIZATION AND CONSERVATION

Plant Biodiversity: Concept, status in India, utilization and concerns.

Sustainable development: Basic concepts.

Origins of agriculture.

World centres of primary diversity of domesticated plants: The Indo-Burmese centre; plant introductions and secondary centres.

Origin, evolution, botany, cultivation and uses of (i) Food, forage and fodder crops, (ii) fibre crops, (iii) medicinal and aromatic plants, and (iv) vegetable oil-yielding crops.

Important fire-wood and timber-yielding plants and non-wood forest products (NWFPs) such as bamboos, rattans, raw materials for paper-making, gums, tannins, dyes, resins and fruits.

Green revolution: Benefits and adverse consequences.

Innovations for meeting world food demands.

Plants used as avenue trees for shade, pollution control and aesthetics.

Principles of conservation; extinctions; environmental status of plants based on International Union for Conservation of Nature.

Strategies for conservation - *in situ* conservation: International efforts and Indian initiatives; protected areas in India – sanctuaries, national parks, biosphere reserves, wetlands, mangroves and coral reefs for conservation of wild biodiversity.

Strategies for conservation - *ex situ* conservation: Principles and practices; botanical gardens, field gene banks, seed banks, *in vitro* repositories, cryobanks; general account of the activities of Botanical Survey of India (BSI), National Bureau of Plant Genetic Resources (NBPGR), Indian Council of Agricultural Research (ICAR), Council of Scientific & Industrial Research (CSIR), and the Department of Biotechnology (DBT) for conservation, non-formal conservation efforts.

Suggested Readings

Anonymous 1997. National Gene Bank: Indian Heritage on Plant Genetic Resources (Booklet). National Bureau of Plant Genetic Resources, New Delhi.

Arora, R.K. and Nayar, E.R. 1984. Wild Relatives of Crop Plants in India. NBPGR Science Monograph No. 7.

Baker, H.G. 1978. Plants and Civilization (3rd ed). C.A. Wadsworth, Belmont.

Bole, P.V. and Vaghani, Y. 1986. Field Guide to Common Indian Trees. Oxford University Press, Mumbai.

Chandel, K.P.S., Shukla, G. and Sharma, N. 1996 Biodiversity in Medicinal and Aromatic Plants in India: Conservation and Utilization. National Bureau of Plant Genetic Resources, New Delhi.

Chrispeels, M.J. and Sadava, D. 1977. Plants, Food and People. W.H. Freeman and Co., San Francisco.

Cristi, B.R. (ed.) 1999. CRC Handbook of Plant Sciences and Agriculture. Vol. I. In-situ conservation. CRC Press, Boca Raton, Florida, USA.

Conway, G. 1999. The Doubly Green Revolution: Food for All in the 21st Century. Penguin Books.

Conway, G. and Barbier, E. 1990. After the Green Revolution. Earthscan Press, London.

Conway, G. and Barbier, E. 1994. Plant, Genes and Agriculture. Jones and Bartlett Publishers, Boston.

Council of Scientific & Industrial Research 1986. The Useful Plants of India. Publications and Information Directorate, CSIR, New Delhi.

Council of Scientific & Industrial Research (1948-1976). The Wealth of India. A Dictionary of Indian Raw Materials and Industrial Products. New Delhi. Raw Materials I-XII, Revised Vol I-III (1985-1992) Supplement (2000).

Cronquist, A. 1981. An Integrated System of Classification of Flowering Plants. Columbia University Press, New York, USA.

Directory of Indian Wetlands, 1993. WWF INDIA, New Delhi and AWB, Kuala Lumpur.

Falk, D.A., Olwell, M. and Millan C. 1996. Restoring Diversity. Island Press, Columbia, USA.

FAO/IBPGR 1989. Technical Guidelines for the Safe Movement of Germplasm. FAO/IBPGR, Rome.

Frankel, O.H., Brown, A.H.D. & Burdon, J.J. 1995. The Conservation of Plant Diversity. Cambridge University Press, Cambridge, U.K.

Gadgil, M. and Guha, R. 1996. Ecology and Equity: Use and Abuse of Nature in Contemporary India. Penguin, New Delhi.

Gaston, K.J. (Ed), Biodiversity: a Biology of Numbers and Differences. Blackwell Science Ltd., Oxford, U.K.

Heywood, V. (Ed) 1995. Global Biodiversity Assessment. United Nations Environment Programme. Cambridge University Press, Cambridge, U.K.

Heywood, V.H. and Wyse Jackon, P.S. (Eds) 1991. Tropical Botanical Gardens. Their Role in Conservation and Development. Academic Press, San Diego.

Kocchar, S.L. 1998. Economic Botany of the Tropics, 2nd edition. Macmillan India Ltd., Delhi.

Kothari, A. 1997. Understanding Biodiversity: Life Sustainability and Equity. Orient Longman.

Kohli, R., Arya, K.S., Singh, P.H. and Dhillon, H.S. 1994. Tree Directory of Chandigarh. Lovedale Educational, New Delhi.

Nair, M.N.B. et al (Eds) 1998. Sustainable Management of Non-wood Forest Products. Faculty of Forestry, Universiti Putra Malaysia. 434004 PM Serdong, Selangor, Malaysia.

Paroda, R.S. and Arora, R.K. 1991. Plant Genetic Resources Conservation and Management. IPGRI (Publication) South Asia Office, C/o NBPGR, Pusa Campus, New Delhi.

Pimentel, D. and Hall, C.W. (Eds) 1989. Food and Natural Resources. Academic Press, London-New York.

Pinstrup-Anderson, P. et al. 1999. World Food Prospects: Critical Issues for the Early 21st Century. International Food Policy Research Institute, Washington, D.C., USA.

Plant Wealth of India 1997. Special Issue of Proceedings Indian National Science Academy B-63.

Plucknett, D.L., Smith, N.J.H., William, J.T. and Murti Annishetty, N. 1987. Gene Banks and Worlds Food. Princeton University Press, Princeton, New Jersey, USA

Rodgers, N.A. and Panwar, H.S. 1988. Planning a Wildlife Protected Area Network in India. Vol. 1. The Report. Wildlife Institute of India, Dehradun.

Sahni, K.C. 2000. The Book of Indian Trees, 2nd edition. Oxford University Press, Mumbai.

Schery, R.W. 1972. Plants for Man. 2nd ed. Englewood Cliffs, New Jersey. Prentice Hall.

Sharma, O.P. 1996. Hill's Economic Botany (Late Dr A.F. Hill, adapted by O.P. Sharma). Tata McGraw Hill Co. Ltd., New Delhi.

Swaminathan, M.S. and Kocchar, S.L. (Eds) 1989. Plants and Society. Macmillan Publication Ltd., London.

Thakur, R.S., Puri, H.S. and Husain, A. 1989. Major Medicinal Plants of India. Central Institute of Medicinal and Anomatic Plants, CSIR, Lucknow.

Thomas, P. 2000. Trees: Their National History. Cambridge University Press, Cambridge.

Wagner, H., Hikino, H. and Farnswarth, N. 1989. Economic and Medicinal Plant Research. Vols 1-3. Academic Press, London.

Walter, K.S. and Gillett, H.J. 1998. 1997 IUCN Red List of Threatened Plants. IUCN, the World Conservation Union. IUCN, Gland, Switzerland, and Cambridge, U.K.

Suggested Laboratory Exercises

The Practical course is divided into three units: (1) Laboratory work, (2) Field survey and (3) Scientific visits.

Laboratory Work

1. **Food crops:** Wheat, rice, maize, chickpea (Bengal gram), potato, tapioca, sweet potato, sugarcane. Morphology, anatomy, microchemical tests for stored food materials.
2. **Forage/fodder crops:** Study of any *five* important crops of the locality (for example fodder sorghum, bajra, berseem, clove, guar bean, gram, *Ficus* sp.).
3. **Plant fibres:**
   (a) Textile fibres: cotton, jute, linen, sunn hemp, *Cannabis*
   (b) Cordage fibres: coir
   (c) Fibres for stuffing: silk cotton or kapok

   Morphology, anatomy, microscopic study of whole fibres using appropriate staining procedures.
4. **Medicinal and aromatic plants**: Depending on the geographical location college/ university select *five* medicinal and aromatic plants each from a garden crop field (*or* from the wild *only* if they are abundantly available).

   *Papaver somniferum, Atropa belladonna, Catharanthus roseus, Adhatoda ceylanica (*Syn *A. vasica), Allium sativum, Rauvolffia serpentina, Withania somnifera, Phyllanthus amarus, (P. fraternus), Andrographis paniculata, Aloe barbadense, Mentha arvensis, Rosa* sp., *Pogostemon cablin, Origanum vulgare, Vetiveria zizanioides, Jasminum grandiflorum, Cymbopogon* sp., *Pandanus odoratissimus.*

   Study of live or herbarium specimens *or* other visual materials to become familiar with these resources.
5. **Vegetable oils:** Mustard, groundnut, soybean, coconut, sunflower, castor.

   Morphology, microscopic structure of the oil-yielding tissues, tests for oil and iodine number.
6. **Gums, resins, tannins, dyes:** Perform simple tests for gums and resins. Prepare a water extract of vegetable tannins (*Acacia, Terminalia*, mangroves, tea, *Cassia* spp, myrobalans) and dyes (turmeric, *Bixa orellana*, indigo, *Butea monosperma, Lawsonia inermis*) and perform tests to understand their chemical nature.

Field Survey

7. **Firewood and timber-yielding plants and NWFP's**
   A. Prepare a short list of 10 most important sources of firewood and timber in your locality. Give their local names, scientific names and families to which they belong. Mention their properties.
   B. Prepare an inventory of the bamboos and rattans of your area giving their scientific and local names and their various uses with appropriate illustrations.
   C. A survey of a part of the town or city should be carried out by the entire class in batches. Individual students will select one avenue/road and locate the trees planted on a graph paper. They will identify the trees, mention their size, canopy shape, blossoming and fruiting period and their status (healthy, diseased, infested, mutilated, misused or dying) and report whether or not the conditions in which they are surviving are satisfactory. The individual reports will be combined to prepare a larger map of the area, which can be used for subsequent monitoring either by the next batch of students/teachers/local communities/NGO's/or civic authorities.

   The purpose of exercise in item C above is to make the students aware of the kinds of trees and value in urban ecosystems and ecological services.

Scientific Visits*

The students should be taken to one of the following:

i. A protected area (biosphere reserve, national park, or a sanctuary)
ii. A wet land
iii. A mangrove
iv. National Bureau of Plant Genetic Resources, New Delhi-110012 or one of its field stations.
v. Head Quarters of the Botanical Survey of India or one of its Regional Circles
vi. A CSIR Laboratory doing research on plants and their utilization
vii. An ICAR Research Institute or a field station dealing with one major crop or crops
viii. A recognized botanical garden or a museum (such as those at the Forest Research Institute, Dehra Dun; National Botanical Research Institute, Lucknow; Tropical Botanical Garden and Research Institute, Trivandrum), which has rich collection of plant products.

***Note:** The students are expected to prepare a brief illustrated narrative of the Field Survey and Scientific Visits. After evaluation, the grades awarded to the students by the teachers should be added to the final assessment of the practical examination.

COURSE IX. BIOTECHNOLOGY AND GENETIC ENGINEERING OF PLANTS AND MICROBES

Biotechnology: Basic concepts, principles and scope.

Plant cell and tissue culture: General introduction, history, scope, concept of cellular differentiation, totipotency.

Organogenesis and adventive embryogenesis: Fundamental aspects of morphogenesis: somatic embryogenesis and androgenesis, mechanisms, techniques and utility.

Somatic hybridization: Protoplast isolation, fusion and culture, hybrid selection and regeneration, possibilities, achievements and limitations of protoplast research.

Applications of plant tissue culture: Clonal propagation, artificial seed, production of hybrids and somaclones, production of secondary metabolites/natural products, cryopreservation and germplasm storage.

Recombinant DNA technology: Gene cloning principles and techniques, construction of genomic/cDNA libraries, choice of vectors, DNA synthesis and sequencing, polymerase chain reaction, DNA fingerprinting.

Genetic engineering of plants: Aims, strategies for development of transgenics (with suitable examples), *Agrobacterium* – the natural genetic engineer, T-DNA and transposon mediated gene tagging, chloroplast transformation and its utility, intellectual property rights, possible ecological risks and ethical concerns.

Microbial genetic manipulation: Bacterial transformation, selection of recombinants and transformants, genetic improvement of industrial microbes and nitrogen fixers, fermentation technology.

Genomics and proteomics: Genetic and physical mapping of genes, molecular markers for introgression of useful traits, artificial chromosomes, high throughput sequencing, genome projects, bioinformatics, functional genomics, microarrays, protein profiling and its significance.

Suggested Readings

Bhojwani, S.S. and Razdan, M.K. 1996. Plant Tissue Culture: Theory and Practice (a revised edition). Elsevier Science Publishers, New York, USA.

Bhojwani, S.S. 1990. Plant Tissue Culture: Applications and Limitations. Elsevier Science Publishers, New York, USA.

Brown, T.A. 1999. Genomes. John Wiley & Sons (Asia) Pvt. Ltd., Singapore.

Callow, J.A., Ford-Lloyd, B.V. and Newbury, H.J. 1997. Biotechnology and Plant Genetic Resources: Conservation and Use. CAB International, Oxon, UK.

Chrispeels, M.J. and Sadava, D.E. 1994. Plants, Genes and Agriculture. Jones & Bartlett Publishers, Boston, USA.

Collins, H.A. and Edwards, S. 1998. Plant Cell Culture. Bios Scientific Publishers, Oxford, UK.

Glazer, A.N. and Nikaido, H. 1995. Microbial Biotechnology. W.H. Freeman & Company, New York, USA.

Gustafson, J.P. 2000. Genomes. Kluwer Academic Plenum Publishers, New York, USA.

Henry, R.J. 1997. Practical Applications of Plant Molecular Biology. Chapman & Hall, London, UK.

Jain, S.M., Sopory, S.K. and Veilleux, R.E. 1996. In Vitro Haploid Production in Higher Plants, Vols. 1-5, Fundamental Aspects and Methods. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Jolles, O. and Jornvall, H. (eds) 2000. Proteomics in Functional Genomics. Birkhauser Verlag, Basel, Switzerland.

Kartha, K.K. 1985. Cryopreservation of Plant Cells and Organs. CRC Press, Boca Raton, Florida, USA.

Old, R.W. and Primrose, S.B. 1989. Principles of Gene Manipulation. Blackwell Scientific Publications, Oxford, UK.

Primrose, S.B. 1995. Principles of Genome Analysis. Blackwell Science Ltd., Oxford, UK.

Raghavan, V. 1986. Embryogenesis in Angiosperms: A Developmental and Experimental Study. Cambridge University Press, New York, USA.

Raghavan, V. 1997. Molecular Biology of Flowering Plants. Cambridge University Press, New York, USA.

Shantharam, S. and Montgomery, J.F. 1999. Biotechnology, Biosafety, and Biodiversity. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

Vasil, I.K. and Thorpe, T.A. 1994. Plant Cell and Tissue Culture. Kluwer Academic Publishers, The Netherlands.

Suggested Laboratory Exercises

1. Growth characteristics of *E. coli* using plating and turbidimetric methods.
2. Isolation of plasmid from *E. coli* by alkaline lysis method and its quantitation spectrophotometrically.
3. Restriction digestion of the plasmid and estimation of the size of various DNA fragments.
4. Cloning of a DNA fragment in a plasmid vector, transformation of the given bacterial population and selection of recombinants.
5. Demonstration of DNA sequencing by Sanger's dideoxy method.
6. Isolation of protoplasts from various plant tissues and testing their viability.
7. Effect of physical (e.g. temperature) and chemical (e.g. osmoticum) factors on protoplast yield.
8. Demonstration of protoplast fusion employing PEG.
9. Organogenesis and somatic embryogenesis using appropriate explants and preparation of artificial seed.
10. Demonstration of androgenesis in *Datura*.
11. Electroporation of protoplasts and checking of transient expression of the reporter gene.
12. Co-cultivation of the plant material (e.g. leaf discs) with *Agrobacterium* and study GUS activity histochemically.

Suggested Readings (for laboratory exercises)

Butenko, R.G. 2000. Plant Cell Culture. University Press of Pacific.

Collin, H.A. and Edwards, S. 1998. Plant Cell Culture. Bios Scientific Publishers, Oxford, UK.

Dixon, R.A. (Ed.) 1987. Plant Cell Culture : A Practical Approach. IRL Press, Oxford.

Gelvin, S.B. and Schilperoort, R.A. (Eds), 1994. Plant Molecular Biology Manual, 2nd edition, Kluwer Academic Publishers, Dordrecht, The Netherlands.

George, E.F. 1993. Plant Propagation by Tissue Culture. Part 1. The Technology, 2nd edition. Exegetics Ltd., Edington, UK.

George, E.F. 1993. Plant Propagation by Tissue Culture. Part 2. In Practice, 2nd edition. Exegetics Ltd., Edington, UK.

Glick, B.R. and Thompson, J.E. 1993. Methods in Plant Molecular Biology and Biotechnology. CRC Press, Boca Raton, Florida.

Glover, D.M. and Hames, B.D. (Eds), 1995. DNA Cloning 1 : A Practical Approach; Core Techniques, 2nd edition. PAS, IRL Press at Oxford University Press, Oxford.

Hackett, P.B., Fuchs, J.A. and Messing, J.W. 1988. An Introduction to Recombinant DNA Techniques: Basic Experiments in Gene Manipulation. The Benjamin/Cummings Publishing Co., Inc Menlo Park, California.

Hall, R.D. (Ed.), 1999. Plant Cell Culture Protocols. Humana Press, Inc., New Jersey, USA.

Shaw, C.H. (Ed.) 1988. Plant Molecular Biology: A Practical Approach. IRL Press, Oxford.

Smith, R.H. 2000. Plant Tissue Culture: Techniques and Experiments. Academic Press, New York.

A TENTATIVE LIST OF ELECTIVE COURSES

1. Advanced Phycology
2. Limnology
3. Microbial Ecology
4. Industrial Microbiology
5. Microbial Genetics
6. Integrated Pest Management: Concepts and Applications
7. Seed Pathology
8. Lichenology
9. Biology of Bryophytes
10. Reproductive Biology
11. Weed Biology
12. Population Biology
13. Forest Biology
14. Biosystematics
15. Molecular Biology and Biotechnology
16. Palaeobotany
17. Plants and Society
18. Advanced Plant Physiology and Biochemistry
19. Crop Genetics and Plant Breeding
20. Plant Tissue Culture
21. Stress Biology
22. Plant Genomics and Proteomics
23. Phytochemistry
24. Arboriculture
25. Plant Propagation: Concepts and Applications
26. Ethnobotany
27. Applied Mycology
28. Molecular Plant Pathology
29. Plant Protection

Interdisciplinary Elective Courses

1. Information Technology
2. Computer Applications and Databases
3. Biostatistics
4. Bioinformatics
5. Phytochemistry and Pharmacognosy

Alternative: Project/Field Work

1. Plant Biodiversity Assessment
2. Conservation of Endangered Species
3. Inventorization of Unexplored Areas and Hotspots
4. Pollution Monitoring
5. Survey of Less-known Economic Plants of India
6. Chromosome Analysis and Indexing of Indian Flora
7. Xenobiotics