PLANT BIOTECHNOLOGY

Comprehensive Biotechnology Second Supplement

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PERGAMON MAJOR REFERENCE WORKS

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Comprehensive Biotechnology (1985)

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Systems & Control Encyclopedia (1987)

Comprehensive Coordination Chemistry (1987)

Comprehensive Polymer Science (1989)

Comprehensive Electrocardiology (1989)

Comprehensive Medicinal Chemistry (1990)

Comprehensive Organic Synthesis (1991)

Comprehensive Rock Engineering (1993)

Foreword

In 1985, *Comprehensive Biotechnology* was published as a major reference work (four volumes; 3764 pages) for effective 'one stop shopping' in a diverse, multidisciplinary field which had previously been treated only in specialist publications. It was well received by the international audience, as shown by citations from *Nature*, the American Chemical Society, the Society for Industrial Microbiology and the Institution of Chemical Engineers, among others.

Since 1985, the biotechnology field has grown significantly, especially in the agriculture-related aspects. To address the changes, the supplement *Animal Biotechnology* was published in 1989 and this year (1992), a complementary supplement *Plant Biotechnology* is being released. As with the first supplement, the editors of *Plant Biotechnology* (M. Fowler and G. Warren) undertook the difficult task of capturing, in an authoritative way, the current status and future trends in this important aspect of biotechnology. We owe them both a word of appreciation for their dedication.

In the future, Pergamon intends to keep the four volume foundation work of *Comprehensive Biotechnology* updated on an ongoing basis with review articles in its quarterly journal, *Biotechnology Advances*.

MURRAY MOO-YOUNG
Waterloo, Canada
June 1991

Preface

Introduction

Some 10 to 15 years ago when the first stirrings of what might be termed 'modern' biotechnology began to take shape, and organizations such as the European Federation of Biotechnology were formed to nurture its development, great doubts were expressed as to the applicability of what might be loosely termed plant sciences to biotechnology. What a difference a decade has made. Today it is generally accepted that one of the key areas of biotechnology for the next century will be in plant-based biotechnology, with implications ranging from improved crops and food provision, to alternative bioremediation systems and novel high value chemicals, including enzymes. Tremendous progress has been made in all aspects of plant physiology, biochemistry and molecular biology over the last decade, much of it driven from a biotechnological standpoint.

The application of novel techniques aimed at improving the performance of plants or plant cells has been a particular growth area in modern biotechnology. Such growth has been directed largely by the needs of agriculture and fuelled by the rapid development of the central techniques of regeneration from plant cell and tissue cultures, gene vector design and plant transformation. Other factors have also been key, notably the interest of many multinational companies who have been quick to see the commercial potential of engineered crop species. Equally, organizations such as the European Commission and World Bank have seen the wider impact upon farming economies and Third World development, and have been instrumental in assembling multinational research programmes focusing on plant biotechnology. In parallel, plant biotechnologists have also recognized that recently unreachable goals have almost overnight come within their grasp, enabling them to reach towards opportunities both scientific and commercial.

Like every branch of biotechnology, plant biotechnology is an ever-broadening subject that is difficult to characterize. We have attempted for ease of presentation to divide this volume into five subject areas.

Biology of Plant Cells

Much that is fundamental to the development of plant biotechnology in the future lies in the structure, composition and functionality of plant cells and genes. It is on this area that the first section focuses, with particular emphasis on the cellular and molecular biology of plants and cultured cells. An appreciation of these basic aspects is important in the recognition of new possibilities and the limitations of many of the individual techniques currently in use. The pursuit of applied aims without due attention to the underlying mechanisms involved is likely to be a self-limiting and inefficient process. This is seen in molecular biology where, while protocols for cloning genes have become almost routine, the question 'which gene shall we clone?' has become commonplace. Plant biotechnology at present is greatly limited by the lack of basic understanding of most of the useful characters we wish to manipulate.

The state of knowledge of plant systems has always lagged far behind that of microorganisms and animals. This to some extent reflects the smaller number of researchers working with plants, but also reflects the technical problems associated with experimentation on plant systems. The new techniques, especially recombinant DNA methods, linked to cell and tissue culture offer great scope to relieve this situation, leading to a deeper and wider appreciation of plant cell and molecular biology.

Systems for the Exploitation of Cell Cultures

This section is concerned with the direct exploitation of cell cultures for the production of useful substances. In principle, this area of research should be perhaps the most immediately fruitful because engineered or selected cells can be produced with characteristics that do not need to be compatible with plantlet regeneration or plant fertility, constraints that have limited progress in certain agricultural applications. However, other obstacles have been encountered, in particular the failure of many cell lines in culture to express those genes coding for secondary metabolite synthesis, genetic instability of cells maintained in culture and the lack of basic information about the biochemistry of biosynthetic pathways. Largely for these reasons, progress in the development of plant cell cultures for industrial use has generally been disappointing. In addition to more basic research, the more widespread adoption of gene transfer methods for the manipulation of pathways may alter this situation. Most likely, plant cell culture will prove to be a feasible route to the production of specific substances in particular, favourable circumstances, for example novel products unique to cultured cells, and the formation of protein products from foreign genes. The alternative strategy of the transfer of plant genes to microorganisms for heterologous expression is also being actively pursued.

Regeneration and Propagation Systems

Central to the application of novel techniques to the improvement of plants is the ability to regenerate whole, fertile plants from individual cells and protoplasts. Although this process was first described some 40 years ago, it has long been restricted to a relatively small range of species. Extensive research has resulted in an improvement in this situation to the point that at least low levels of regeneration are now possible from most of the important crop species. However, much of the progress has been empirically based, and plant regeneration is still devoid of a satisfactory theoretical foundation. The desired applications of cell fusion and transformation techniques have placed extra demands on regeneration systems. The requirement that newly developed plant varieties must be compatible with breeding programmes necessitates high fertility of the regenerants. This situation is usually the exception rather than the norm. It has been found that, although transformation and regeneration can often be readily achieved separately, transformation of regeneration competent cells is much rarer, and therefore the frequency of transgenic plants recovered can be very low. New developments are occurring rapidly in this area, however, and the recent reports of fertile, transgenic rice and maize perhaps indicate that these problems are near to a general solution.

Plant regeneration has long been exploited commercially for the micropropagation of ornamentals and disease-free stock. However, tissue culture techniques are labour intensive and time consuming and careful planning is required to ensure that a micropropagation scheme is economically viable. There is currently increasing interest in the mechanization of certain culture manipulations with a view to reducing the cost of the process.

Genetic Manipulation of Plant Cells

The next section considers the increasingly central area of genetic manipulation of plant cell systems. For a number of years, manipulation of the genetic make-up of plants by protoplast fusion, mutagenesis and culture-induced variation has resulted in steady but relatively slow progress towards improved plant varieties. Now specific gene transfer has moved to centre stage. The ability to add just the desired genes to a plant, without the near certainty of downgrading previously optimized characters, gives special appeal to this approach. However, the other novel methods will continue to be useful in specific instances, especially in cases in which there is little understanding of the molecular mechanisms governing the desired characters. Traditional methods will probably remain central to crop improvement but will be increasingly complemented by the new technology. Biotechnology is all about application and commercialization. The technique that achieves the desired aim most cheaply will be adopted and not necessarily that which is novel, or technically most elegant or sophisticated.

Genetic engineering has already been responsible for the production of plants with enhancement in a range of desirable traits, notably disease resistance, insect resistance, ripening properties and nutritional and commercial value. Progress is also being made towards longer term aims such as improvement of the efficiency of photosynthesis and other polygenic mechanisms. Enthusiasm for transgenesis is currently high. The bounds of the possible have been radically widened. However, this enthusiasm is being tempered by the growing debate on the potential hazards of releasing transgenic plants, the ethical and emotional concerns associated with changing our flora, and whether there is an actual need to create certain new plant varieties.

This book is a survey of these various facets of plant biotechnology. The individual chapters and the follow-up literature cited should allow a relatively easy access to the various subject areas and hopefully stimulate interest in these rapidly moving and exciting fields of research.

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June 1991

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