Isolation and Culture of Plant Protoplasts

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Within recent years techniques have been developed to isolate viable plant protoplasts in large numbers from higher plant cells by removing the cell wall with the help of enzymes. It has thus become possible to do a variety of experiments and manipulations with the plant protoplast which had so far been out of reach of botanists. The knowledge gained from the work on plant protoplasts during the last few years is of far-reaching theoretical and practical importance. It is the purpose of this article to bring this information and the possible future uses of isolated and viable plant protoplasts to the attention of a wide spectrum of botanists in the hope that the techniques of the isolation and culture of plant protoplasts can be used to probe various aspects of growth and differentiation in plants.

The cell wall around the plant protoplast is required not only for the proper physiological functioning of the plant cell system, but also for providing the necessary mechanical strength to plants which normally lack skeletal structure and organization. In addition, the cell wall of plant cells is of considerable historical, cultural and economic importance to man in the form of cotton, flax, or jute and other vegetable fibers, in the manufacture of finer grades of paper, as source of timber, lumber, etc. The presence of a rigid cell wall is, however, of considerable disadvantage to those interested in conducting a variety of experiments involving plant cells and tissues for studies on nucleo-cytoplasmic interaction, the role of the nucleus and the cytoplasm in controlling various phases of differentiation and growth, somatic hybridization, and in many areas of plant physiology, plant pathology, morphogenesis and genetics.

Animal cells, which lack a cell wall, have been used extensively with remarkable success for studies involving nuclear transplants and cell fusion (Ephrussi & Weiss, 1965; Harris, 1970; Harris et al., 1966; Ebert & Sussex, 1970). Also, bacterial (Weibull, 1958) and fungal (Bachmann & Bonner, 1959) protoplasts have proved to be of unique value in morphological, biochemical and genetic studies microorganisms. Another plant used widely for similar studies, thanks to the classic studies of Hammerling and later of Bracket, is the unicellular alga Acetabularia, which can be grown easily in the laboratory, has a vulnerable nucleus located in one corner of the highly differentiated and large cell, and has an exceptionally good ability for regeneration after surgical treatments.

Methodology. Mechanical methods such as microdissection, stripcutting and partial homogenization have been used from the end of the 19th century to obtain a few viable protoplasts from higher plant tissues. These protoplasts can be maintained in salt solutions for several days. In 1960, Cocking at the University of Nottingham developed a technique for the isolation of very large numbers of plant protoplasts. This method involved the enzymic degradation of the cell wall by cellulase from M. raffinose prunus cerasaria. Similar forms of cellulase have since been used to isolate protoplasts from root, cotyledon, leaf, coleoptile, fruit and other tissues of plants (Cocking, 1960; Gregory & Cocking, 1961 1965; Ruesink & Thimann, 1965, 1966). Others have used pectinase followed by endohydase, a mixture of pectinase and cellulase (from Trichoderma viride), or partially purified enzymes, with improved results (Takebe et al., 1968; Schenk & Hildebrandt, 1970; Schenk & Hildebrandt, 1971).
The occurrence of pinocytosis in plant cells has been suggested by many authors to explain the uptake and transport of various substances, including virus particles. A direct and substantive proof of pinocytotic effects of auxins on membrane permeability probably play an important role in the rapid elongation of the cell wall (Power & Cocking, 1970; van Steveninck, 1965) and may also affect the pattern of protein and nucleic acid synthesis (Davis et al., 1968).

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uptake of polystrene latex particles (Mayo & Cocking, 1969); ferritin and tobacco mosaic virus particles (Power

- Cocking, 1970; Cocking, 1966, 1970; Aoki & Takebc, 1969; Takebe & Otsuki, 1969) has been provided by using isolated plant protoplasts. It has also been shown by similar experiments using the differential staining effects of phosphotungstic acid on the plasma membrane that certain regions of the plasmalemma which take up the stain have a distinct and different chemical composition than the unstained areas of the plasmalemma, and all other organelle membranes including the tonoplast (Mayo & Cocking, 1969). The presence of vesicles in the cytoplasm with comparable staining reaction suggests that these vesicles have arisen by infoldings of the plasmalemma, and the detection of exogenously supplied ferritin in such vesicles establishes that these are pinocytotic vesicles. Isolated plant protoplasts have to be maintained in suitable but complex nutrient media often containing as much as 20n sucrose. In view of the fact that pinocytosis can be induced or inhibited by a variety of substances, it is not clear whether the extent of pinocytosis observed in isolated protoplasts is close to or greatly in excess of that in the normal plant cell.

Cell Wall Regeneration in Protoplasts. Regeneration of cell walls by isolated protoplasts of fungi (Bachmann & Bonner, 1959); yeasts (Necas, 1965); and higher plant cells ( Nagata & Takebe, 1970; Pojnar et al., 1967; Mishra

- Colvin, 1969) have been demonstrated, and the importance of such systems for studying the mechanism and chemistry of cell wall deposition is quite obvious. Mishra

- Colvin (1969) have shown with the help of electron microscopic and x-ray diffraction studies that the newly-formed cell wall around isolated tomato-fruit protoplasts is not a typical plant cell wall and the origin and composition of its various layers are not yet known. Cell wall regeneration occurs soon after the protoplasts are removed from the pectinase-celulase solution and seems to depend on the presence of the nucleus, as enucleate sub-protoplasts fail to regenerate a cell wall. Re-generation usually results in the formation of single spherical cells but cell aggregates can be obtained if protoplasts are kept in contact with each other during cell wall re-generation (Pojnar & Cocking, 1968).

Cell Division in Reconstituted Protoplasts. One (if the difficulties often encountered in the culture of plant protoplasts has been the apparent inability of the protoplasts to undergo mitotic divisions. One to two nuclear divisions have recently been observed in protoplasts of Haploppus grecilis Erickson & (onass, 1969). Recently, Nagata & Takebe (1970) and Tao et al. (1970) were not only able to re-generate cell walls in protoplasts obtained from tobacco leaf mesophyll cells and soybean cells in suspension culture, but were also able to induce repeated mitotic divisions in the newly reconstituted cells resulting in the formation of groups of eight or more cells. Isolated moss protoplasts readily regenerate cell wall in culture, and then form protonemata and whole plants (Binding, 1966).

Fusion of Isolated Protoplasts. One of the most important and far-reaching aspects of the development of precise techniques to isolate and successfully culture plant protoplasts is the fact that isolated protoplasts fuse to form he tend-avorous under suitable emu-lit-ions (Power et al., 1970; Cocking, 1971). Washing the protoplasts with (1.25M sodium nitrate seems to induce fusion, probably by affecting the electrical and physiological properties of the plasmalemma. The presence of an inactivated virus is not required for bringing about the fusion of plant protoplasts although that is a pre-requisite for obtaining fusion of animal cells.
One of the important applications of the technique of isolation and culture of plant protoplasts could be the possibility of making inter- and intra-specific nuclear or cell organelles (plastids, mitochondria, dictyosomes, ribosomes, etc.) transplants for understanding problems of the control of growth, differentiation and morphogenesis.


The Doctor of Arts in Botany

With increasing emphasis being placed upon ecology, environmental pollution, and the conservation of natural and human resources, many institutions are restructuring their biological programs to prepare students for active and productive careers in these fields. The Claremont Graduate School, Claremont, California has recently approved a new Doctor of Arts degree program in the Biological Sciences, with emphasis on Botany. The Doctor of Arts program is presented as a way of better training botanists for participation in biology programs in state, liberal arts, and community colleges. The program would be tailored to the needs and interests of the individual student and would be formulated to give him a broadly based background in the biological and environmental sciences with major emphasis on plant science.

The Ph.D. program would remain what it has been, a program for research oriented students who will most likely find employment in universities where emphasis is shared between teaching and research.

To the limits of the faculty’s ability, the two programs would remain equal as to qualifications for entrance, the quality of performance required of the student. The Doctor of Arts would not be considered a second-rate Ph.D. or a substitute for the Ph.D. The two would be considered equal but with different goals.

The academic requirements for admission to the Doctor of Arts program will be the same as for admission to the Ph.D. program. Students holding an M.S. degree from an acceptable institution would be allowed to transfer up to 24 units of class work. The decision on the suitability of the courses for transfer and the number of units allowed will be made by the faculty.

In recent years the graduate student population in botany has varied from 7 to 11. It is not anticipated that this number will be greatly increased in the foreseeable future. If a Doctor of Arts program is given it is expected that there will be no more than one of two students en-rolled in it at any one time and that the total number of students in botany will be no more than it would be with-out the program.

It is not anticipated that there will be any difficulty in recruiting students and already there are two who have indicated that they would like to enroll this coming fall if such a program is available. One has a M.S. and since 1967 has been an instructor in biology at Youngstown State University, Ohio. The other will receive his B.A. this June from the University of Maryland and has indicated an interest in preparing for college teaching. One advanced and one beginning student would give a desirable spread at the beginning of the program.

Full-time students in botany who hold graduate traineeships now enroll for two classes each semester from the botany curriculum. In addition, they enroll for independent research, tutorial reading, master’s thesis or doctoral study (as appropriate). Students in the Doctor of Arts program would also enroll for two classes from the botanical curriculum and in addition would elect one course each semester from the zoological and microbiological curricula. Some time during their program they would also enroll for two courses in Education. The first year would involve 24 units of class work and seminars; the second year would involve 24 units of class work and seminars. The third year would be a teaching internship, also for 24 units.

A qualifying examination shall be taken not later than the end of the second year of study.

Summer Programs: During the first two summers, field experience would be gained by enrolling for studies at one or more biological stations or laboratories. The choice of the station, or laboratory, would depend upon the student’s interests and needs. Examples of acceptable institutions are: Santa Catalina Marine Biological Laboratory, Hopkins Marine Station, University of Michigan Biological Station, the Smithsonian Institution Biological Station, Barro Colorado Island. Canal Zone or biological program. Office of Tropical Studies, San Jose, Costa Rica.

One foreign language is required and in addition one of the following: a second foreign language; a suitable course in statistics or computer science; or Advanced Techniques in Botanical Research.

Each candidate for the Doctor of Arts degree would be required to present a review paper on some suitable subject. The subject and scope of the paper to be approved by a faculty committee in consultation with the student.

Editor’s Notes

The editor is pleased to report that former editor Dr. Harry J. Fuller is very much alive and presently is residing at The Americana Nursing Center in Urbana, Illinois. Sincere apologies are extended to both Dr. Fuller and to his friends for referring to the “late” Dr. Fuller in the last issue of PSB.

Reaction to the new format has been very good, and apparently the BULLETIN is reaching the membership in good condition despite being mailed “flat”. Suggestions that will result in an improved PSB are always welcome, as well as contributed papers. news_announcements, and the like.

News & Announcements

First International Congress of Systematic and Evolutionary Biology

The Society of Systematic Zoology and the International Association for Plant Taxonomy have joined forces to develop this first opportunity for botanical/zoological inter-action at the international level. The University of Colorado (Boulder, Colorado) has extended a gracious invitation to meet on that campus August 4-11, 1973. The diversity of ecological situations in the surrounding country-side makes this one of the most attractive sites in North America, both aesthetically and scientifically. The presence of experienced, enthusiastic biologists on that campus also provides an indispensable ingredient for the success of this Congress.

Program plans at this point encompass interdisciplinary symposia and contributed paper sessions. The botanists will not convene a nomenclatural session but a zoological one on this subject is anticipated. In the next few months the outline of the program and other activities will begin to take form. All suggestions will be gratefully received, carefully considered, and as many adopted as practical or feasible. Correspondence may be addressed to the Secretary: Dr. James L. Reveal. Department of Botany, University of Maryland. College Park. Maryland 20740.

Taxonomy and Phytogeography of Higher Plants in Relation to Evolution

This conference has been organized by Professor D. H. Valentine on behalf of the Linnean Society of London, the Botanical Society of the British Isles and I. O. P. B. It will be held at the Botany Department, University of Manchester, England on 9th-11th September, 1971. The programme will be grouped into sections covering the following topics:—I. Floristic elements. 2. Major geographical disjunctions in relation to evolution and migration—(a) Vicarious species; (b) Migration. 3. Endemism—(a) Evolution of island floras; (b) Special topics. 4. Geographical evolution in general of special interest. Among those from whom provisional acceptances to speak have been received are:—Prof. J. Korns (Krakow), Prof. H. Ilara (Tokyo), Prof. T. W. Bocher (Copenhagen), Dr. D. M. Moore and Dr. D. Bramwell (Reading), Dr. D. F. Cutler (Kew), Prof. O. T. Solbrig (Harvard), Dr. W. Grouther (Geneva), Prof. H. Lewis (Los Angeles, California), Plotz. C. Favarger (Neuchatel), Prof. C. van Steenis (Leiden), Dr. N. Jardine and Dr. S. M. Walters (Cambridge), Dr. A. Strid (Lund), Dr. H. G. Baker (Berkeley, California) and Professor A. R. Clapham, F.R.S.
Eunice Rockwell Oberly Memorial Award

A biennial award has been established, to be given in odd-numbered years, and consisting of a citation and a cash award from the income of the Oberly Memorial Fund. It is to be administered by the Agricultural and Biological Sciences Subsection, Subject Specialists Section, Association of Colleges and Research Libraries of the American Library Association.

The award will be made to the American citizen who compiles the best bibliography in the field of agriculture or in one of the related sciences in the two-year period preceding the year in which the award is made. The fund was established by colleagues in memory of Eunice Rockwell Oberly. Additional information regarding this award can be obtained from Mr. Fleming Bennett, University of Florida Libraries, Gainesville, Fla. 32601.

Field Biology on Nantucket Island - Massachusetts

The Biology Department of the University of Massachusetts - Boston will offer a course in field biology at its research facility on Nantucket Island from July 25 through September 1 this summer. The course is designed for advanced undergraduates and offers six credits. Each student is required to conceive of, carry out and write up an original research project in field biology. A number of habitats allowing, study of both plants and animals are available at or near the Research Center. These include salt marsh and estuarine areas, shallow coastal waters, sand dune, moorland and upland scrub. Limited living facilities are available at modest cost. Students desiring more detailed information concerning admission and conduct of the course should contact Wesley N. Tiff net Jr., Biology Department, University of Massachusetts—Boston, 100 Arlington St., Boston, Mass. 02116.

American Journal of Botany Reprint Policy

Owing to increasing costs and decreasing revenues, Dr. Lawrence J. Crockett, Business Manager, American Journal of Botany, regrets to announce that the very liberal rule that everybody who publishes in the journal receives the first 100 reprints free must be changed. Beginning with the August issue, only those who are paying the voluntary page charge will get the reprints free.

Hopefully, members of the Society will understand why this change is necessary. Our membership dues are very low in comparison to other similar scientific societies. It has been possible for a member who published two articles in one year to get back as much as S30.00 on his $10.00 membership fee. While finances were rosy, this could be tolerated, but with science and economics being what they are today, the Society can no longer grant this gift.

Agronomists Announce Meeting

The American Society of Agronomy and its two sister societies, Crop Science Society of America and Soil Science Society of America, have announced preliminary plans for their 1971 annual meeting to be held in New York City, August 15-20. Theme of this year's meeting is "Agronomy and Environmental Quality." This meeting has the potential of being the greatest agronomic gathering in the Societies' history.

Through the special symposia that are planned, the Societies will have the opportunity of speaking to scientists in related disciplines, the layman public and the press about the position of the agronomic sciences on the environmental issues of today. Some of the symposia to be held are: Breeding Crops for Resistance to Insects; Fate and Economic Impact of Herbicides in the Environment; and Sediments and Water Quality.

Dr. Norman E. Borlaug, who has been called the father of the green revolution for his invaluable work in developing high-yield wheat strains, is to be the guest of honor and featured speaker at a combined session of the Crop Science Society of America and Soil Science Society of America. This session will be held at 8:00 p.m., Monday, August 16, as a feature event of the annual meeting of the American Society of Agronomy and these two societies.

Dr. Borlaug's topic will be "Potentials and Limitations of Improving Crop Varieties to Meet World Food Needs." He has devoted his talents and energies toward improving and expanding crop yields and duality since 1944 and feels the greatest problem mankind must solve is development of ways and means of feeding the expanding world population.

Because of his untiring efforts for humanity, Dr. Borlaug has been awarded the Nobel Prize for Peace. Of this, Dr. Borlaug, has said. "It is not my prize, but a prize for agriculture."

The Second National Biological Congress

The Second National Biological Congress will be held in one of the most delightful spots in the United States. Miami Beach. It begins on 23 October and continues through 26 October 1971. There will he 3 days of symposia, partly on very general topics and partly on more specific problems. There will also he social events, a few major speeches, and biological field trips.

The theme is "Man and Environment II," and will focus specifically on: What are the problems posed by our environment? What success have we had so far in dealing with them? and What is the outlook?

The morning programs will center on three practical aspects of the work of biologists in relation to the environment:

BIOLOGISTS AS PLANNERS

Ecological Engineering
organized by Athelstan Spilhaus
Problems of Developing the New World
To he announced
Ecology & the Planning of Future Cities
organized by Keith Hay
Agriculture in an Urban Society
organized by Edward J. Ryder
Scientific Aspects of Human Population Control To be announced

BIOLOGISTS AS OBSERVERS

Radiation: Its Control & Future Dangers
organized by Alexander Hollaender
Primary Productivity
organized by Robert Whittaker and Gene Likens
Our Mobile Earth
organized by William Benson
results from other tundra sites, such as those in Russia, Norway and Alaska.

The research is part of the 5-year, 60-nation International Biological Program organized by William Benson

World Trends in Epidemic Diseases organized by Marshall Laird

World Trends in our Environment organized by Thomas F. Malone

BIOLOGISTS AS PROBLEM SOLVERS Problems of Sewage organized by Gilbert Levin

Weather Modification: Ecological Opportunities and Environmental Problems organized by Charles Cooper & Frank Eden (Cosponsored by the American Meteorological Society) The International Biological Program organized by I. W. Frank Blair

Strategy of Approaching World Protein Food Problems organized by Aaron A. Altschul

Past, Present, and Future of the Everglades organized by Howard Teas

The New Knowledge of Auto-Immunity organized by S. B. Beck

To be announced

The program will also include a special symposium to celebrate the Bicentenary of the Discovey of Photosynthesis, and the Atwater Memorial Lecture Award, presented to a leading scientist who will speak on problems of nutrition and the world's food supply.

The afternoon programs are being planned by the biological societies. At this time, these include American Society of Biological Chemists, American Society for Horticultural Science, American Society of Parasitologists, American Society of Zoologists, Society of Invertebrate Pathology, Society for the Study of Evolution, The Nature Conservancy, National Wildlife Federation, The Wildlife Society, The Teratology Society. American Society for Experimental Pathology, and Federation of American Societies for Experimental Biology. Mane of these societies will have joint programs.

The last day of the Congress has been set aside for biological field trips. South Florida is an extremely interesting area biologically, and the weather in October is ideal. Visits will include Everglades National Park, Fair-child Tropical Garden, Plant Introduction Station, Pigeon Key Marine Station, Scaquarium, and the Lerner Marine Laboratory at Bimini.

For further information about the Congress, and for registration and housing arrangements, Society members should write to the National Biological Congress, American Institute of Biological Sciences, 3900 Wisconsin Ave., N. W., Washington, D. C. 20006.

University of Montana Biological Station Program

The Biological Station, a unit of the Summer Session of the University of Montana, has announced its program for 1971. The Station, located at Yellow Bay, Flathead Lake, Bigfork, Montana will offer six courses in botanical science during the summer session June 27-August 21. Systematic Botany, Phylogeny, Morphology, Problems in Taxonomy, Mycology, and General Ecology will be given together with selected courses in Zoology. The faculty will be Drs. John Tibbs, Director. Arden Gadsden, Gerald W. Prescott. B. L. Turner, Robert L. Fisher, Edward E. C. Clebsch, Orson K. Miller, Benjamin A. Foote, and James J. O'Toole. Persons interested in the program, or in opportunities for study and research at the Station should write to Dr. Tibbs, Biological Station, University of Montana, Missoula, Montana 59801, or care of the summer mailing address University of Montana Biological Station, Bigfork, Montana 59911.

Dr. John Walton, 1895-1971

John Walton, regius professor of botany at the University of Glasgow from 1930 until 1962, died on February 13th in Dundee, Scotland.

A Fellow of the Royal Society of Edinburgh and a Corresponding Member of the Botanical Society of America, Professor Walton was internationally famous for his studies of Paleozoic plants. His influence has been felt, knowingly or unknowingly, by every paleobotanist who ever made a cellulose acetate peel or a transfer preparation of a fossil specimen because he originated both of these basic and indispensable techniques. Indeed, progress in the field of paleobotany has been so greatly facilitated by their universal application that, without any discredit to his man's important botanical contributions, they can be considered Professor Walton's most significant contributions to science.

Professor Walton was born in London, and educated at Edinburgh and Cambridge. In 1921 he was botanist with the first Oxford expedition to Spitzbergen. Following his retirement he was given the honorary appointment, Dean of Faculties, by the University of Glasgow. He received Doctor of Science degrees from Cambridge and Manchester, honorary Doctor of Science degrees from Montpellier and Lille, and an honorary Doctor of Laws degree from McMaster.

In addition to his interests in morphology and paleobotany he had a deep concern for nature and its conservation. This interest, which persisted throughout his life-time, is reflected in certain positions he held. He was President of the Glasgow Tree Lover's Association and the Scottish Youth Hostels Association, a forestry commissioner, and a member of the Scottish Committee of the Nature Conservancy.

His interests also encompassed the fine arts, and he served as honorary curator of the University of Glasgow's art collections.

Professor Walton visited North America on several occasions, and will be remembered personally by his many American and Canadian friends amongst whom are several who studied under him as exchange students or post-doctoral fellows.

Charles B. Beck

Personalia

Dr. Anton Lang, director of the AEC Plant Research Station at Michigan State University, has been appointed chairman of the NAS/NRC group studying the effects and dangers of herbicides and defoliation in Vietnam.

Dr. Barbara McClintock, Carnegie Institution of Washington, was among the recipients of the 1970 National Medal of Science, the highest award of the federal government for distinguished achievement in science, mathematics, and engineering. She was recognized for her re-search in establishing the relations between inherited character of plants.

Two Colorado botanists have received a National Science Foundation grant to conduct a study of the growth and development of plants common to the Rocky Mountain tundra regions of Boulder county and to various arctic regions of the world. Dr. Erik K. Ronde, University of Colorado, and Mrs. Maxine Foreman, Denver Community College, will conduct the studies at the University, and at the Institute of Arctic and Alpine Research Station during the 1971-72 year. Plants will be grown at the experimental gardens ranging in altitude from 5500 feet at Boulder to 12,300 feet at Niwot Range, and comparisons will be made with results from other tundra sites, such as those in Russia, Norway and Alaska. The research is part of the 5-year, 60-nation International Biological Program (IBP).
The articles are all written by experts in the several fields. They are highly informative, profusely and beautifully illustrated, and in a clear, concise and interesting manner give the results of scientific research in the broad range of areas discussed. Of course, reprinting articles as they were originally published over a span of years leaves some of them not entirely up to date, but this is not a serious handicap. The interested student can be encouraged to pursue recent work in any area that stimulates his interest.

This book contains some of the most fascinating aspects of botany and agriculture and demonstrates the vital importance of plants and plant studies to human life and civilization. It should be useful as collateral reading in general biology and botany courses as well as in courses in economic botany and others dealing with resources and population problems. High school and college teachers of biology would profit by reading this book. It should help them and their students to realize that plants, plant science and technology are as interesting and important as any-thing man studies, and are, moreover, the most "relevant" studies of our time. This is an attractive, interesting and convenient compilation. It deserves to be widely read.

Sydney S. Greenfield


This book, a proceedings of the NATO Ege University Summer Institute held in Izmir, Turkey in 1967, consists of 25 papers presented by a fairly impressive array of authorities. The subject matter dealt with is for the most part auxin transport and its effects on correlation phenomena.

Joseph Scheibe


Anyone who intends to use this collection should read the preface; it is well written and informative. Students in particular should be referred to the note on reading scientific papers. The objective of the collection is to assemble under one cover a few of the recent, most readable and most interesting scientific research papers which reflect the breadth of plant physiology and illustrate some of the current trends in the field. No particular effort has been made to include classical papers rather those which are especially well written and fairly brief. Indeed, as the compiler points out, inclusion of a paper "does not necessarily imply that it is highly original or fundamental in its area" and "an equally appropriate collection could be made without including any of the papers chosen". It does not seem appropriate to consider "papers chosen". It does not seem appropriate to consider "possible exceptions are of high scientific quality. The compiler himself notes that inclusion in this volume is neither a guarantee of quality nor any assurance the work will stand the test of time.

The intended use of this collection, especially for teaching purposes, is less clear. Presumably, the collection would be used by undergraduate students or even beginning graduate students in order to make it easier for the student (or the teacher) to find some good research papers. I certainly favor the idea of having undergraduate students (even first-or second-year students who are interested) read a few original research papers. These can convey the excitement of science and a feeling for the process of scientific inquiry; however, this collection isn't necessary to achieve that goal.

I think it would be very difficult for a student to set each report into the broader perspective and see its contribution to the development of its special area. Thus, it would be very helpful for the student to have some sort of introduction to each of the six sections. The compiler recognizes this shortcoming and concludes, probably correctly, that it would be impossible to produce these summaries in a brief form. If the collection had focused on six important lines of investigation, rather than trying to span the entirety of plant physiology, it might have been possible to provide a brief summary-overview for each section. Concentration on a couple of important themes would also have enabled even the uninitiated reader to observe and understand the evolution of some important principles.

In conclusion, the job done by this collection could have achieved more economically and perhaps more effectively by a list of suggested readings at the end of each chapter in a plant physiology text (this reinforced by the instructor's encouragement to read some original papers). This would have the advantage that the text itself would help the student to see Lou each research report contributed to the development of the field.

Terry D. Nooden

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Dr. Arthur II. Westing, Department of Biology, Wind-ham College, Putney, Vermont 05346, is conducting re-search on the ecological impact of bomb craters. He would be interested in corresponding with anyone who has any information on the literature of this subject.