Recent Advances in Phytochemistry 45

Reinhard Jetter *Editor*

The Formation, Structure, and Activity of Phytochemicals

Springer

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Volume 45

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Preface to the 45th Volume of the Recent Advances in Phytochemistry Series

Welcome to the fifth volume since the reintroduction of the *Recent Advances in Phytochemistry* (*RAP*) series, an annual journal of the Phytochemical Society of North America. *RAP* is dedicated to publishing both review and primary research articles for a broad audience of biologists, chemists, biochemists, pharmacologists, clinicians, and nutrition experts, especially those interested in the biosynthesis, structure, function, and/or bioactivity of plant natural products. Recurring themes include the evolution and ecology of specialized metabolites, the genetic and enzymatic mechanisms for their formation and metabolism, the systems biology study of their cell/tissue/organ context, the engineering of plant natural products, as well as various aspects of their application for human health. In addition, also new developments in the techniques used to study plant natural products are presented and discussed, for example, for structure elucidation and quantification, for "omic" (genomic/proteomic/transcriptomic/metabolomics) profiling, or for microscopic localization. In short, this series combines chapters from researchers that explain and discuss current topics in the most exciting new research in phytochemistry.

Two main types of articles are published in *RAP*: Perspectives and Communications. The *RAP* Perspectives aim to give a general introduction to a field and an overview of the pertinent literature, as a background for understanding new results from the primary literature and (in many cases) previously unpublished results. These articles may be similar to review articles, but also are intended to present important ideas and hypotheses, and may put forward proposals for interesting new research directions in the field. It is the hope of the Editorial Board that these articles will be of great value to a large audience. The *RAP* Communications focus more on primary data and synthesize only a small number of papers, to showcase particular new advances in a field that will be of interest to a large audience. Articles of both types are typically solicited from prominent members of the Phytochemical Society of North America, based on the content of presentations at the annual meeting. However, the Editorial Board also invites additional Perspectives and/or Communications from selected authors beyond the society's meeting to give a rounded picture of all "Recent Advances in Phytochemistry."

All submissions to *RAP* go through a rigorous, external peer review process, overseen by the Editorial Board. *RAP* is indexed together with all other journals published by *Springer*. All *RAP* papers are available not only in the published volume form, but also electronically through *Springer*'s online literature services. This marks a significant change from past volumes of *RAP*, and it is the hope of the Editorial Board that this will lead to broader dissemination and greater interest in *RAP*.

This 45th volume of *RAP* includes a total of eight chapters, many, but not all, based on talks presented at the 52nd annual meeting of the Phytochemical Society of North America. As was seen in *RAP* volumes 41–44, these papers span the breadth of plant (bio)chemistry research in North America, which is also indicative of the state of the field worldwide. The first article presented here reviews the 50-year history of the Phytochemical Society of North America, thereby highlighting research milestones of the past decades. The other seven chapters describe the integration of several different approaches to ask and then answer key questions regarding the function of interesting plant metabolites, either in the plant itself or in chemical ecology or human health application.

Two perspectives focus on chemical structure elucidation: Nikolić et al. summarize new findings on the nitrogen-containing compounds found in Black Cohosh (*Actaea racemosa* syn. *Cimicifuga racemosa*), while Ling et al. give an overview of natural products in various *Jatropha* species along with other Euphorbs.

Two other chapters give updates on the biosynthesis of selected plant natural products. In one of them, Umezawa et al. summarize recent progress on *O*-methyltransferases involved in the formation of lignans. Next, Kumar et al. review the biosynthesis and functions of the plant hormone salicylic acid and its derivatives.

Two more perspectives focus on phytochemicals involved in interactions between plants and pathogens or insects. In particular, Chezem and Clay review recent literature on the regulation of enzymes involved in formation of phenylpropanoids and aromatic alkaloids, whereas Jeschke et al. summarize the current understanding of phytochemical metabolism in insect herbivores.

Finally, a communication by Sumarah et al. provides primary data on the isolation of novel fungal endophytes from Eastern white pine (*Pinus strobus*), and on their secondary metabolites enhancing pathogen tolerance of the host tree.

Overall, we are excited to present this broad set of review papers on various aspects of modern Phytochemistry. We hope you will find them to be interesting, informative, and timely. It is our goal that *RAP* will act not only as the voice of the Phytochemical Society of North America, but that it will serve as an authoritative, up-to-date resource that helps to set the standard for thought and research in plant natural products. Enjoy the read!

The RAP Editorial Board

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Chapter 1
A Half-Century of the Phytochemical Society of North America: 1961–2011

Stewart A. Brown, Constance Nozzolillo, and Tom J. Mabry

Abstract In this chapter, the history of the Phytochemical Society of North America (PSNA) is reviewed on the occasion of its 50th anniversary. The formation of the PSNA's precursor organization is described, and its transformation to the present society, whose scope and coverage are discussed. The main body of this chapter consists of summaries of the meetings in each of the PSNA's five decades held annually at diverse sites in the USA, Canada, and Mexico, and twice in Europe jointly with the Phytochemical Society of Europe. Other joint meetings have been held with four other cognate societies. The format of the meetings is organized around a symposium topic discussed by several invited speakers, and has usually included contributed papers. The talks have been published first as individual books by the PPGNA and later by the PSNA in the annual series entitled *Recent Advances in Phytochemistry (RAP)*, sometimes replaced more recently by a special issue of *Phytochemistry*. Other publications are briefly discussed: the newsletter, meeting programs, and the website maintained this century by technically knowledgeable volunteer members. Executive functions have also been the responsibility of senior volunteer members. Membership, mostly from the USA, Canada, and Mexico, also includes many foreign phytochemists. A student membership has aimed from earliest days to encourage participation in the Society's activities by young scientists through lower membership and meeting registration fees, competitions with prizes awarded for best oral or poster presentation, assistance with travel expenses to attend meetings, and, in 2007, formation of a Young Members Committee. Awards

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by the Society have been Life Memberships, since 2006 the Phytochemical Pioneer Award to senior North American and foreign phytochemists, and since 1995 the Arthur Neish Young Investigators Award tied to a minisymposium by student members at many of the annual meetings. Tribute is paid to those whose efforts have been responsible for the success and survival of the Society for so many years.

Keywords Plant Phenolics Group of North America (PPGNA) • Annual meetings • Publications of the PPGNA • Phytochemical Society of Europe (PSE) • American Society of Pharmacognosy (ASP) • Awards • Officers • Presidents

1.1 The Early Days as the Plant Phenolics Group of North America

The last day of August 1961 saw the beginning of a 2-day symposium at Colorado State University, Fort Collins, entitled *Biochemistry of Plant Phenolic Substances*. Organized by Gestur Johnson of the host university and Ted Geissman of the University of California, Los Angeles, it had seven invited speakers, including two from Japan, covering topics on the chemistry, biosynthesis, and animal metabolism of this group of compounds. Although certainly timely and important in furthering interest in this nascent but growing field, the major historical significance of the Fort Collins meeting was that on the second day the assembled specialists in plant phenolics from the USA and Canada held the organizational meeting of the Plant Phenolics Group of North America (PPGNA). An executive committee was formed at this organizational meeting, with Simon Wender of the University of Oklahoma as the first President, Leonard Jurd of the United States Department of Agriculture, Albany, California, as Vice-President, and Victor Runeckles of Imperial Tobacco Company of Canada, Ltd., Montreal, Quebec, as Secretary-Treasurer.

In retrospect, the run-up to the founding of the PPGNA is worth noting. It was not the first such organization globally, as a plant phenolics group had been formed several years earlier in Britain that aroused interest across the Atlantic. In fact, as one of us has outlined in a history of the Phytochemical Society of North America (PSNA) published on the occasion of the Society's 30th anniversary in 1991 (S.A. Brown, *RAP* Vol. 26 pp. 377–393), it was the attendance of Neil Towers of McGill University at one of their meetings and his resulting enthusiasm that was a major factor leading to informal discussions at the Ninth Botanical Congress in Montreal in 1959 about the possibility of forming a counterpart in North America. This idea was explored further by Neil Towers, Runeckles, and Ted Geissman. Concurrently, Eric Conn of the University of California, while on sabbatical leave at Cambridge in the spring of 1960, attended a meeting of the British society with Tony Swain and Jeffrey Harborne. He also thought it would be great to have a similar organization in the USA and Canada, and then when he returned he found that steps were already being taken to start such an organization. When funds became available to Gestur Johnson from the National Science Foundation 2 years later for

a symposium on plant phenolics, it was decided that it should be the venue for launching a plant phenolics organization on this side of the Atlantic. This led to the 2-day meeting discussed at the beginning, with further details to be found in the abovementioned history (pp. 378–381), at which the PPGNA was formally launched.

1.2 Evolution to the Phytochemical Society of North America

The transition from the Plant Phenolics Group to the PSNA occurred in three major stages between 1965 and 1967. First, it was formally proposed to the membership. Although these symposia and the associated sessions of original presentations were deemed to have been largely successful, there was some sentiment in the PPGNA almost from the outset that the Society would benefit from extending its coverage to other classes of plant secondary metabolites. This view was by no means universal, but what tipped it in the direction of expansion was a formal proposal adopted at the 1965 meeting that the PPGNA become a phytochemical society. Because of its basic importance and long-term implications the proposal to form such a society was approved by a majority of the membership in a mail vote.

Next, an executive committee and constitution were established. To get the ball rolling Bernie Finkle of the United States Department of Agriculture in Albany, one of the organizers of the 1965 meeting, approached Tom Mabry of the Botany Department at the University of Texas in Austin on behalf of the PPGNA executive about the possibility of his hosting the following year's meeting at that institution. Mabry, an organic chemist who had been engaged to set up a plant chemistry program in that department, had an interest in phytochemicals that extended well beyond phenolics. He had quite recently finished a postdoctoral research project on the identification of betanidin under André Dreiding at the University of Zürich. He concurred with the request, but only if the meeting were to cover different classes of natural products and not just phenolics. This condition, which was in accordance with the decision to expand the scope of the Society, was accepted by the executive.

Finally, a new format for the meetings had to be established. Mabry's initial task was to obtain funding to bring European phytochemists to Austin. Fortunately, W. Gordon Whaley, a Botany Professor and Dean of the College of Natural Sciences at Austin, agreed to provide most of the funding needed for the meeting. The Department also undertook to fund two European visiting professors during the spring of 1966: W.D. Ollis of the University of Sheffield and Dreiding, both of whom agreed to speak at the April 1966 symposium. Holger Erdtman of the Royal Institute of Technology, Stockholm, Sweden, Anders Kjaer and Martin Ettlinger, Royal Veterinary and Agricultural College, Copenhagen, Denmark, N.A. Sørenson, Norway Institute of Technology, Trondheim, Norway, Hans Grisebach, University of Freiburg, Germany, and G. Ponsinet, Institute of Chemistry, Strasbourg, France, provided a further international complement to the list of speakers that also included Frank Stermitz, Colorado State University, Werner Herz, Florida State University,

and Ralph Alston, The University of Texas. The talks were presented in four parts: (1) The role of chemistry in modern biology, (2) nitrogen and sulfur compounds, (3) acetate- and mevalonate-derived compounds, and (4) flavonoids, and they were published as Volume 1 of *Recent Advances in Phytochemistry* (*RAP*) by Appleton Century Crofts Press. The papers were edited by Mabry, Alston, and Runeckles. Sadly, Dr. Alston (1925–1967) did not live to see this volume in print. It is dedicated to his memory and his many publications in the field of genetics and chemistry of plant secondary compounds.

At this meeting the PSNA was formally established, with appropriate changes to the constitution. On January 1, 1967, it came into legal existence, with Mabry serving as its first President. The post of Secretary-Treasurer of the former PPGNA had been split, with A.J. Merritt becoming the first Secretary and Howard Wright Treasurer.

1.3 Scope and Coverage of the PSNA

A definition of the scope and coverage of the Society was offered soon after its formation. In the preface to a 1963 symposium Runeckles described the PPGNA as *"an informal association of scientists of various disciplines, which aims to promote the furtherance of phenolic and related plant constituents as regards their chemistry, biochemistry, and physiological and pathological effects, and the application of such knowledge to industry and agriculture."* Deletion of "informal" and "phenolic and related" would still today produce a fair description of the PSNA. Since its inception it has concentrated its attention on secondary plant products, as opposed to those of mainstream anabolic and catabolic reactions involving substances not unique to plants, but usually found in the metabolic pathways of animals and microbes.

At that time, secondary plant products were largely ignored and even scorned by many in biochemistry and botany/plant biology, and plant physiology texts made little or no mention of them. They were regarded as of no significance in comparison to the essentiality of the "primary" compounds such as amino acids and sugars, or the intermediates and products of photosynthesis that may be considered to represent mainstream plant biochemistry. But of course, it is the vast array of secondary products that, in addition to the photosynthesis-related metabolites, make the metabolism of plants, these incredibly complex chemical factories, unique and distinctive. Those who published in this field at that time frequently complained about the reluctance of mainstream biochemical journals to accept manuscripts based on research in this field, and of granting agencies to support such research. The founding of *Phytochemistry* as a specialty journal catering to studies of secondary metabolism helped greatly in correcting this bias, but there is no doubt that the existence of the PSNA and its European counterpart, the Phytochemical Society of Europe (PSE), have also made a major contribution to greatly increased recognition of research on plant secondary metabolism in recent decades.

1.4 Relations with Cognate Societies

The Society was well into its second decade before it moved formally into relationships with cognate organizations. No scientific society exists in a vacuum, and interaction with cognate organizations leads to very desirable cross-fertilization, often including collaborative research. Recognizing this, the PSNA has met jointly on several occasions with related groups, most prominently twice with the PSE, on both sides of the Atlantic. These meetings have been adjudged generally successful in bringing together phytochemists from two continents, and probably only the factors of distance and expense, together with greater organizational problems, have rendered such joint meetings relatively infrequent. It is clearly desirable to hold more of them in future if possible.

There have also been joint meetings with other cognate societies on several occasions. These have included two meetings each with the American Society of Pharmacognosy and the International Society of Chemical Ecology (ISCE), as well as one joint meeting with the American Society of Plant Physiologists (now the American Society of Plant Biologists), and one with the Mid-Atlantic Plant Molecular Biology Society, all generally regarded as productive and worthwhile. Further mention of these joint meetings can be found below in the accounts of the individual meetings.

1.5 Annual Meetings and Publication of Symposia in *Recent Advances in Phytochemistry*

It is, of course, in the interests of a society to hold its meetings in as diverse locations as circumstances permit. A varied environment is thus assured, and members in different localities who might be financially or otherwise constrained from attending meetings far afield are encouraged to participate in more of them. The PSNA has had much success in such diversification. With the great majority of its members resident in the USA the annual scientific and business meetings have naturally been held predominantly in that country. Through 2011 fifteen states have been host to the annual gatherings, several of them more than once (Table 1.1). Four Canadian provinces and three Mexican states have also been meeting sites, in harmony with the North American scope implied in the Society's name. The meeting sites have ranged from the Atlantic at Boston to the Pacific at Vancouver, from the sprawling metropolis of Mexico City to the small community of Cullowhee, North Carolina, in the foothills of the Appalachians, from the Canadian Rockies to the tropical island of Hawaii and the plains of Oklahoma, and from the Cajun atmosphere of New Orleans to the French-Canadian ambiance of Quebec City. But the fact remains that lower population density in most of North America compared to Europe has not permitted meetings more often than annually, and this has imposed some restrictions on meeting site diversity.

Table 1.1 Meeting sites, symposium titles, and corresponding volume numbers of the recent advances in phytochemistry (*RAP*)[a]

Year	Location	Symposium title	RAP Vol.
1961	Fort Collins, CO	Biochemistry of plant phenolic substances	
1962	Corvallis, OR	Plant phenolics and their industrial significance	
1963	Toronto, ON	Aspects of plant phenolic chemistry	
1964	Norwood, MA	Phenolics in normal and diseased fruits and vegetables	
1965	Albany, CA	Phenolic compounds and metabolic regulation	
1966	Austin, TX	Recent advances in phytochemistry	1
1967	Madison, WI	Phytochemical techniques	2
1968	Tucson, AZ	Phytochemistry and the plant environment	3
1969	Banff, AB	Enzymology and biochemistry of phenolics	4
1970	Beltsville, MD	Structural aspects of phytochemistry	5
1971	Monterrey, Nuevo Leon	Terpenoid chemistry and biochemistry	6
1972	Syracuse, NY	Chemistry and biochemistry of plant hormones	7
1973	Pacific Grove, CA	Metabolism and regulation of secondary plant products	8
1974	Cullowhee, NC	Phytochemistry in relation to disease and medicine	9
1975	Tampa, FL	Biochemical interaction between plants and insects	10
1976	Vancouver, BC	The structure, biosynthesis and degradation of wood	11
1977	Gent, Belgium	Biochemistry of plant phenolics	12
1978	Stillwater, OK	Topics in the biochemistry of natural products	13
1979	De Kalb, IL	Resource potential in phytochemistry	14
1980	Pullman, WA	Phytochemistry of cell recognition and cell surface interactions	15
1981	Ithaca, NY	Cellular and subcellular localization in plant metabolism	16
1982	Ottawa, ON	Mobilization of reserves in germination	17
1983	Tucson, AZ	Phytochemical adaptation to stress	18
1984	Boston, MA	Chemically mediated interactions between plants and other organisms	19
1985	Pacific Grove, CA	The shikimate pathway: recent developments	20
1986	College Park, MD	The phytochemical effects of environmental compounds	21
1987	Tampa, FL	Opportunities for phytochemistry in plant biotechnology	22
1988	Iowa City, IA	Plant nitrogen metabolism	23
1989	Vancouver, BC	Biologically active products of the mevalonic acid pathway	24
1990	Quebec City, QC	Modern phytochemical methods	25
1991	Fort Collins, CO	Phenolic metabolism in plants	26
1992	Miami Beach, FL	Phytochemical potential of tropical plants	27
1993	Pacific Grove, CA	Genetic engineering of plant secondary metabolism	28

(continued)

Table 1.1 (continued)

Year	Location	Symposium title	RAP Vol.
1994	Mexico City, DF	Phytochemistry of medicinal plants	29
1995	Sault Ste. Marie, ON	Phytochemical redundancy in ecological interactions	30
1996	New Orleans, LA	Food phytochemicals: flavors, stimulants and health promoters	31
1997	Leiden, The Netherlands	Plant communication with the environment	32
1998	Pullman, WA	Phytochemicals in human health protection, nutrition, plant defense	33
1999	Montreal, QC	Evolution of metabolic pathways	34
2000	Beltsville, MD	Regulation of phytochemicals by molecular techniques	35
2001	Oklahoma City, OK	Phytochemistry in the genomics and post-genomics eras	36
2002	Mérida, Yucatan	Integrative phytochemistry; from ethnobotany to molecular ecology	37
2003	Peoria, IL	Secondary metabolism in model systems	38
2004	Ottawa, ON	Chemical ecology and phytochemistry in forest ecosystems	39
2005	La Jolla, CA	Integrative plant biochemistry as we approach 2010	40
2006	Oxford, MS	(No specific topic)	
2007	St. Louis, MO	(No specific topic)	
2008	Pullman, WA	(No specific topic)	
2009	Towson, MD	Biologically active phytochemicals	41
2010	St. Petersburg Beach, FL	Natural solutions to 21st century problems	42
2011	Hilo, HI	The biological activity of phytochemicals	43

[a]Beginning in 1966 the symposia were published as *Recent Advances in Phytochemistry* by the following publishers: Vols. 1–4, 1966–1969 Appleton Century Crofts; Vols. 5–8, 1970–1973 Academic; Vols. 9–33 1974–1998 Plenum; Vols. 34–40 1999–2005 Pergamon; Vol. 41 2009 Springer

Although a society with small membership faces not a few challenges, in one respect it has a distinct advantage. In marked contrast to the mega-meetings of larger societies that can be accommodated only in major cities with attendant high expense, the small size of the PSNA has usually permitted its annual meetings to be held at smaller locations, often on the campuses of universities in small or moderately large communities. Although Boston, Toronto, Vancouver, Tampa, Mexico City, and Montreal have all been sites for meetings, they have been more typically held in such places as Cullowhee in North Carolina, Stillwater in Oklahoma, Pacific Grove in California; Banff in Alberta; Pullman in Washington, and Ithaca in New York. A fairly relaxed and intimate atmosphere has thus typically prevailed.

As can be seen below, the symposia from most of the meetings over the years have also been published in the *RAP* by several publishing firms (Table 1.1). These published volumes have proved to be an important resource for researchers seeking to keep apace of the latest developments in phytochemistry.

1.5.1 The First Decade

Beginning in 1962 more symposia were scheduled by the PPGNA: *Plant Phenolics and their Industrial Significance* at Corvallis, Oregon, in August of 1962, *Aspects of Plant Phenolic Chemistry* in Toronto in September 1963, *Phenolics in Diseased Fruits and Vegetables* at Norwood, Massachusetts, in July 1964, and *Phenolic Compounds and Metabolic Regulation* at Albany, California, in August 1965. The first three of these were published by the Society in soft cover, and the 1965 symposium in Albany was the first to appear in hard cover, in a book entitled *Phenolic Compounds and Metabolic Regulation*.

The second meeting of the fledgling PSNA was in August of 1967 at Madison, Wisconsin, to hear six speakers on the symposium topic *Phytochemical Techniques*. These included instrumental methods such as nuclear magnetic resonance, mass spectrometry and gas chromatography, plant tissue culture and chemical methods applied to lignin structure elucidation. The talks were published as Volume 2 of *RAP* by the same press, again under only the general title of *Recent Advances in Phytochemistry* with no mention of the specific subject. The papers were edited by Margaret Seikel and Victor Runeckles.

The third meeting of the PSNA was preceded by the tenth anniversary meeting of the British group at Cambridge University in the spring of 1968, attended by about 130, mostly locals but also by a large contingent of assorted Europeans and at least two members of the PSNA, Conn and Mabry. Participants stayed in almost luxurious quarters: brand new residences of Emmanuel College vacated by the students during their holiday break, where most of the very good meals were provided, and in whose common room the annual dinner, preceded by a sherry reception, was held. The cost of registration was, yes, £4! The scientific sessions were held in the anatomy building down the road from the college. It was at this meeting that one of the present authors (C.N.), who was not yet a PSNA member, was converted from plant physiologist to phytochemist. The revelation of the fundamental role of phenylalanine not only in "primary metabolism" such as protein synthesis but also in "secondary metabolism" such as lignin synthesis and flavonoid pigments in the life of a plant was confirmed by Conn, her tablemate at dinner, discoverer with his student Jane Koukol of the enzyme phenylalanine ammonia lyase (PAL). Later in 1968 the PSNA met at the University of Arizona in Tucson with the topic *Phytochemistry and the Plant Environment*. The 11 talks covering subjects such as stress factors, fungal and insect resistance were published as *RAP* Volume 3 edited by Steelink and Runeckles.

The following year the PSNA met at the Banff School of Fine Arts in Alberta, in a meeting organized by Victor Runeckles and John Watkin that must surely be considered one of the most successful ever. Its symposium title was *Enzymology and Biochemistry of Phenolics*. Advantage was taken of the spectacular backdrop of the Canadian Rockies by adoption of a format analogous to that of the Gordon Conferences, in which the meetings were scheduled morning and evening, with the afternoons left open for informal discussions but also allowing participants to mount

excursions to the many points of interest within easy reach of the meeting site. The talks were later published as *RAP* Volume 4, edited by the organizers, with the first chapter devoted to aromatic amino acid metabolism, the second to PAL, the third to cinnamic acid metabolism, the fourth to flavonoid evolution, the fifth to furanocoumarins, the sixth to the possible role of phenolics in regulation of germination, the seventh and eighth on lignin, and the ninth on major frontiers in phytochemistry.

In October 1970, the meeting organized by Tien Tso in Beltsville, Maryland, was attended by all three of the present authors. Nozzolillo recalls presenting a talk on anthocyanins, whose colors were matched by beautiful red and blue bruises on her face that had resulted from an encounter with a post at the airport! The 11 invited talks were published as *RAP* Volume 5 by Academic Press and edited by Runeckles and Tso, but with the title of the symposium predominant on the cover: *Structural and Functional Aspects of Phytochemistry*. Since the speakers included the eminent plant physiologists Winslow Briggs and Arthur Galston, primary metabolism such as photosynthesis and phytochrome action predominate in the first four chapters. Mabry et al. begin discussion of secondary metabolism in Chap. 5 with betalains. The remaining six chapters are then devoted to various other aspects of phytochemistry.

October was again the month selected for the 1971 meeting in Monterrey, Mexico, on the topic of terpenoids. The nine invited talks were published by *RAP* as Volume 6, edited by Runeckles and Mabry under the title *Terpenoids: Structure, Biogenesis, and Distribution.* The first two chapters are contributions from the Universidad Nacional Autónoma de Mexico, the third from CNRS in France, the fourth, and seventh to ninth from universities in the USA with contribution to one of them by Ernst von Rudloff of the National Research Council of Canada. The sixth by A. Ian Scott et al. of Yale departs somewhat from the theme by discussing indole alkaloids.

1.5.2 The Second Decade

Chemistry and Biochemistry of Plant Growth Regulators was the topic of the symposium organized by Ernest Sondheimer et al. at the 1972 meeting in Syracuse, New York, and the title of *RAP* Volume 7. As was the case for the 1970 meeting, the topic chosen overlaps with the "primary" aspects of plant physiology. These growth hormones, although not essential to basic metabolism and present in vanishingly small amounts, were recognized as nevertheless playing a very important role in plant development. Two chemists from England updated information on structure of the terpenoid gibberellins and abscisic acid, respectively, while an American reported on the purine-derived cytokinins. Three plant physiologists discussed how indoleacetic acid, gibberellin, and ethylene, respectively, function in the plant. R.M. Silverstein's banquet address on chemical communication among insects, or sex and the single insect, was an indication of the ecological interests of many members that would culminate in the formation of the ISCE a decade later. The