CHAPTER 11

RESEARCH INTO THE VOLATILE OILS OF THE AUSTRALIAN FLORA, 1788–1967

H. H. G. McKern,

". . . Where blossom'd many an incense-bearing tree;
And here were forests ancient as the hills, . . ."

—SAMUEL TAYLOR COLERIDGE, "Kubla Khan".

THE BEGINNINGS: 1788-1850

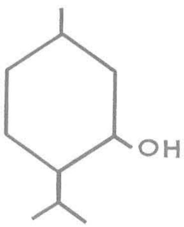
This title may appear to indicate a somewhat more specialized field of science than those treated in some other chapters of this publication, but it may be justified in a centenary volume of the Royal Society of New South Wales, with its implications of the history of both the Society in particular, and of Australian science in general. Firstly, natural plant products, amongst which are included volatile or essential oils, were among the first objects of enquiry by the more educated and speculative minds of the first European settlement at Port Jackson; an enquiry which grew both with the geographical advance of colonization, and, with the efflux of time, with increase of scientific knowledge. Secondly, it was through the Royal Society of New South Wales that there was made public over the years a very considerable corpus of new knowledge on this subject; in the Society's *Journal* there are recorded over 100 papers in the field. Thirdly, as a result of these researches, organic chemists the world over have been given access to a number of unusual and interesting chemical compounds from the Australian flora, which have initiated or given stimulus to many research projects. Finally, a practical outcome of these investigations has been the establishment of an industry which for over a century has provided both local employment and export earnings for the nation. This chapter in Australian science has thus fulfilled one of the wishes of the founders of the Society, established "to encourage studies and investigations in, and to receive at its stated meetings, and to publish original papers on Science, Art, Literature and Philosophy, and especially on such subjects as tend to develop the resources of Australia, and to illustrate its Natural History and Productions".

Reference has just been made to the examination of natural products by the first colonists of this country in the year 1788 and in the years immediately succeeding. Indeed, as early as 1802, Lord

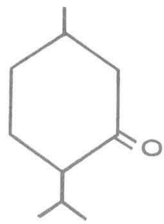
Hobart advised Governor King to see that ships returning from the colony were laden with natural products to lessen "the burthen at present borne" by the mother country. Native timbers appear to have been the chief of these early exports, although small quantities of grass tree resin (from *Xanthorrhoea*) and vegetable dyestuffs were also sent.

It comes as somewhat of a surprise, however, to learn that the first specimen of a natural product to leave these shores was a volatile plant oil—the leaf oil of *Eucalyptus piperita,* a tree still to be found growing naturally on such of the sandstone shores of Port Jackson as have not yet been denuded of their natural flora. A classical operation of organic chemistry—steam distillation—was carried out within the first two years of existence of the infant colony, and the result is recorded in the Appendix of the "Journal of a Voyage to New South Wales" of John White, Surgeon-General to the Colony, and published in London in 1790. This appendix was written by Dr. J. E. Smith, founder of the Linnean Society, and he records that "The name of Peppermint Tree has been given to this plant by MR. WHITE on account of the very great resemblance between the essential oil drawn from its leaves and that obtained from the Peppermint (*Mentha piperita*) which grows in England. This oil was found by MR. WHITE to be much more efficaceous in removing all cholicky complaints than that of the English Peppermint, which he attributes to its being less pungent and more aromatic. A quart of the oil has been sent by him to *Mr. Wilson*". Surgeon Considen was probably associated with Surgeon-General White in these early experiments; in a letter to Sir Joseph Banks from Port Jackson dated November 18, 1788, ten months after the establishment of the colony, he writes: "We have a large peppermint tree, which is equal, if not superior, to our English peppermint. I have sent you a specimen of it. If there is any merit in applying these and many other simples to the benefit of the poor wretches here, I certainly claim it, being the first who discovered and recommended them." There is here no direct reference to *oil,* but among Sir Joseph Banks' papers, under date November 17, 1789, there is reference to a sample of eucalyptus oil which had been sent by Governor Phillip in the ship *Golden Grove.*

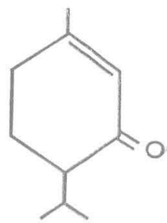
Chemical evidence now available shows how acute was the judgement of White and Considen in applying oil of *Eucalyptus piperita* or "Sydney peppermint" as a substitute for peppermint oil as a carminative. The chief constituents of peppermint oil from *Mentha piperita* are menthol (I) and menthone (II). The chief constituent of the oil of the foliage of *E. piperita* found on the shores of Port Jackson is piperitone (III), first isolated and characterized by H. G. Smith in 1900, who was wont to refer to it as his "peppermint ketone". Its odour is strongly reminiscent of oil of peppermint, consistent with its close structural relationship to menthone and menthol. Indeed, as will be noted later, Smith and Penfold, in demonstrating in 1920 the structure of piperitone, showed that it could be reduced to menthone, and thus laid the foundations of the industrial preparation of synthetic menthol, as an alternative to the isolation of the natural substance from oil of peppermint.



I. Menthol.



II. Menthone.



III. Piperitone.

However, systematic investigation and exploration of the volatile oils of the Australian flora at this level had to wait; at the time of these early essays, the science of organic chemistry had not yet arisen, and the struggling colonists, bond and free, had more urgent matters to occupy their energies. It was not until the decade 1850-1860 (when the Royal Society of New South Wales was taking its present form) that the systematic examination and commercial production of these oils commenced, and have flourished side by side uninterruptedly to the present day.

Bosisto and von Mueller: The Fifties to the Nineties

Research into the volatile oils of the Australian flora was initiated in Victoria in the early fifties of the last century by the English pharmacist, Joseph Bosisto (1822-1898). He commenced by carrying out a series of experimental steam-distillations of the foliage of a number of plant species with the object of learning something of their properties, and of the uses to which they might be put.

Bosisto was a Yorkshireman who originally intended to study medicine, but on transferring in the forties to London, he became increasingly interested in pharmacy, and he entered the School of Pharmacy in Bloomsbury Square. The nineteenth-century pharmacist was obliged to possess a considerable knowledge of chemistry and botany, and to be able himself to prepare many of his drugs and chemicals, as well as to analyse them for purity. It was the possession of this training which enabled Bosisto, on migration to Australia in 1848, to make the first significant contribution to our knowledge of these oils, and, by the early fifties, within a few years of opening his pharmacy in Richmond, near Melbourne, he was experimenting with the steam-distillation of the foliage of many different indigenous plant species collected from the vicinity of Melbourne.

With the name of Bosisto should be linked that of the botanist, Baron Ferdinand von Mueller (1825-1896). Born in Rostock in Germany, he too, like his future colleague Bosisto, commenced his professional studies in pharmacy. Finding the botanical aspects of pharmacy to his liking, he studied this science intensively at the University of Kiel, where he received the degree of Doctor of Philo-

Joseph Bosisto.
(Photo: Museum of Applied Arts and Sciences)

sophy at the age of 21. Young Mueller was not very robust, and for health reasons decided to migrate to South Australia, where he arrived in 1847. He obtained employment as a pharmacist, but devoted his leisure time to the botanical exploration of his new country. His zeal and rapidly-acquired knowledge of the flora of south-eastern Australia led to his appointment in 1853 as Government Botanist of Victoria, and from that year onwards to his death in 1896, his labours constitute a notable chapter in the annals of Australian botany. Among his many other achievements, von Mueller found time to translate into English Wittstein's "The Organic Constituents of Plants and Vegetable Substances", published in Melbourne in 1878, and thereby demonstrated his continuing interest in plant chemistry; von Mueller never ceased to advocate the exploration of the chemical products of the flora of the land of his adoption. In fact, whilst Director of the Melbourne Botanic Gardens, he had asked that a laboratory be built in the grounds, so that chemical research, similar to that carried out by Wittstein in Munich, might be instituted. In 1924, Charles Daley wrote of him in the *Victorian Historical Magazine*: "Impressed by the valuable hygienic and medical properties of the eucalypts, as revealed in the close observation of the many species, the Doctor advocated, and with Mr. Bosisto in 1854, instituted the process of distilling oil from the leaves, an activity which has now assumed tremendous proportions." Bosisto acknowledged his indebtedness to von Mueller in a paper to the Royal Society of Victoria: ". . . I would say that I cannot too strongly express the obligations under which Dr. Mueller, the Government botanist, has placed me in common with all those who are on any account interested in the botany of Victoria by his assiduous and untiring researches and by the various able and valuable works in which he has embodied the results of his investigations, nor should I personally feel justified in omitting to express my sincere thanks for the courteous kindness with which Dr. M. has always afforded me information on these subjects and the readiness which he has always displayed to assist my inquiries." Indeed, this paper, entitled "On Essential Oils from Native and Imported Plants", read before the Society on July 28, 1862, and recorded in its *Transactions*, is of some significance in the history of Australian phytochemistry. It is the first communication from a scientist working in this country on the volatile oils of the Australian flora, and which was published in the journal of a local learned society.

The relationship between these two men has been treated here at some length, since not only does their collaboration mark the real commencement of the industrial exploitation of the volatile oils of the Australian flora, but it also marks the beginning of a century of continued effort in Australian phytochemistry, characterized also in later years, as at the beginning, by collaboration of chemist and botanist.

By the sixties of the last century, Bosisto had established oil of eucalyptus as a commercial product:* he exhibited this and the oils of other genera at the Melbourne Exhibition of 1862 (of this Exhibition Bosisto wrote: ". . . I had the honour of exhibiting twenty-eight samples of Volatile Oils from native plants") and in 1868 sent a large collection of Australian essential oils to the Paris Exhibition of that year. Bosisto was an active man of many interests: he was elected first president of

* The price quoted at the London International Exhibition of 1862 was six shillings per gallon.

the Pharmaceutical Society of Victoria, was thrice Mayor of Richmond, and in 1874 was elected a member of the Legislative Assembly of Victoria where he sat for 15 years. He was honoured by Queen Victoria with the order of Commander of St. Michael and St. George, and was elected in 1887 an honorary member of the Pharmaceutical Society of Great Britain. As well as expressing his broad scientific interests as an active member of the Royal Society of Victoria, he was also largely instrumental in the framing of the Pharmacy Act and in the setting up of the Pharmacy Board. He was a prominent member of those who established the Melbourne College of Pharmacy, where he acted as Examiner in Materia Medica, and he founded the *Australasian Journal of Pharmacy*.

As a consequence of Bosisto's pioneering efforts, the commercial distillation of eucalyptus oil spread, as the demand grew, from Victoria to South Australia (especially on Kangaroo Island), and to Tasmania where oil of the Tasmanian "blue gum" (*Eucalyptus globulus*) was a regular article of trade by the early eighties; in 1888 Bosisto is recorded as employing a staff of 40. However, the eucalyptus oil reaching the European market during the first 30 or 40 years of the industry was of a variable nature. There were two main reasons for this: firstly, the taxonomy of the Australian flora was still in an unsettled state, and confusion of species, each yielding its characteristic oil, resulted in variable chemical compositions of the distilled products. Organic chemists were ignorant, not only of the constituents of the oils of the Australian flora, but of the whole class of chemical compounds now called the terpenes. Hence, until the pioneer researches of the late nineteenth century into this chemical class had made some progress, notably through the labours of Otto Wallach, it was not possible to distil or utilize these oils on a rational basis. To bring these matters into historical perspective, it might be recalled that Wallach did not commence his classic researches until 1884, and that the structure of the molecule of the commonest terpene, α-pinene, was not settled until as late as 1896 through the work of Wagner and of Baeyer.

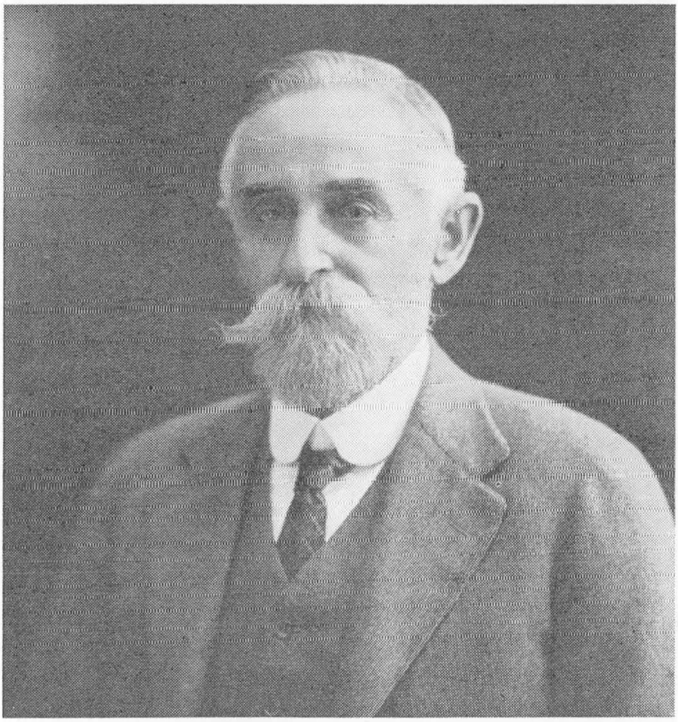
It is therefore one of the many tributes that can be paid to the memory of Henry George Smith (1852-1924) that his first essential oil paper appeared as early as 1897, when he reported to the Royal Society of New South Wales his work on the oil of *Eucalyptus piperita*, and announced the discovery of a new compound, eudesmol. Further, by 1902, he and his botanical colleague, Richard Thomas Baker (1855-1941), had already published the first edition of their famous monograph on the oils of the Eucalypts, better known in its second edition of 1920. In 1910 they published the monograph "The Pines of Australia", and this and the "Research on the Eucalypts" were not only scientifically important in their day, but also remain memorials to the quality of Australian book production of the time.

Baker and Smith: 1897-1920

This second stage of research into volatile plant oils in Australia is marked, then, by the fruitful partnership of H. G. Smith and R. T. Baker of the Museum of Applied Arts and Sciences in Sydney, at that time known as the Sydney Technological Museum. This period,

Richard T. Baker.
(Photo: Museum of Applied Arts and Sciences)

which may be taken as beginning with their first paper on essential oil chemistry in 1897, thus commenced also approximately at the time of the deaths of von Mueller in 1896, and of Bosisto in 1898, and may be considered as extending to 1920, the year in which both Baker and Smith retired. Before considering the contribution of Baker and Smith, it should not be forgotten that it was a botanist, Joseph Henry Maiden, F.R.S. (1859-1925) who launched these two forth on to their life work in phytochemistry. Like Mueller, Maiden had acquired some chemical knowledge, both theoretical and practical, at the University of London, and also recognized the enormous and barely-touched opportunities for phytochemical research in Australia. Before his appointment in 1896 as New South Wales Government Botanist and Director of the Sydney Botanic Gardens, he was the first Curator of the Museum, and it was he who was responsible for initiating systematic and extensive investigations at that institution into the chemistry and possible economic applications of the natural products of the local flora.



Henry George Smith.
(Photo: Museum of Applied Arts and Sciences)

In anticipation of essential oil researches, he had had a still erected at the Museum, but on his transfer to the National Herbarium shortly after, it was left to Smith to operate it. Smith joined the staff of the Museum in 1884, and in 1891 had published his first chemical paper. His first paper in organic chemistry appeared in 1895 with Maiden as co-author, the subject being the kino or gummy exudations of *Eucalyptus* species; Baker joined the Museum in 1888, and on Maiden's transfer to the Botanic Gardens, became Curator and Economic Botanist. Baker and Smith then settled down to the field into which they had been directed by Maiden, Baker concentrating on the botanical aspects of the work, whilst Smith, commonly regarded as the father of organic chemistry in Australia, carried out the chemical work. Biographical material on Baker* and on Smith† is readily accessible, and a colour film on Smith has been produced by the Australian Commonwealth Film Unit,‡ and consideration should now be directed to their work.

J. H. Maiden.
(Photo: Museum of Applied Arts and Sciences)

This first impresses by its very amount, and secondly, because it represented such an advance from the pre-terpene chemistry era of Bosisto, who could do little more than record the physical properties of the oils. Smith, on the other hand, could conduct fractional distillations (albeit rough), and could demonstrate the presence of a compound by

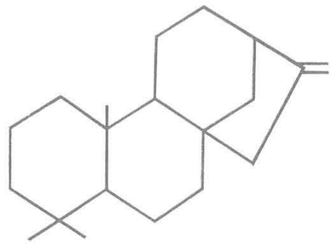
* *Proc. Linnean Soc. New South Wales,* 67 (1942) i-ii; *Proc. Roy. Soc. New South Wales,* 76 (1942) 6; The Australian Encyclopaedia, vol. 1, 393 (Grolier Soc. of Aust., Sydney, 1965).

† D. P. Mellor, "H. G. Smith—a Pioneer in Australian Phytochemistry", *Proc. Roy. Aust. Chem. Inst.,* 27 (1960) 309-316.

‡ This very fittingly received its first public screenings at the International Symposium on the Chemistry of Natural Products, organized by the Australian Academy of Science and held under the auspices of the Section of Organic Chemistry of the International Union of Pure and Applied Chemistry at Melbourne, Canberra and Sydney, August 15-25, 1960.

the preparation of a derivative, and could recognize and characterize a new compound when he encountered it. By establishing the approximate compositions of these oils in the light of the newly-established facts of terpene chemistry, then being increased rapidly by the efforts of Semmler, Tiemann, Baeyer, Wagner and many others, a clearer indication as to economic potential was possible. The botany of the Australian flora had also made progress, and the clarity of botanical description accompanying the chemical work eliminated the older botanical confusion in commercial distillation practice, and clearly recognized oils or classes of oils conforming to a specified trade requirement were now marketed. As an illustration of this progress, it may be mentioned that the sole criterion upon which a medicinal-type oil of *Eucalyptus* was judged in the British Pharmacopoeia as late as the 1885 edition was that the specific gravity should be "about 0·900". By 1914, however, this publication required the chemical composition to be indicated by conformity with limits for a number of physical properties, and in addition, specified a minimum cineole content, and the absence of α-phellandrene.

The labours of Baker and Smith were the beginnings of modern essential oil research in Australia. They worked on a Commonwealth-wide basis, drawing their experimental material from all States, in many instances from regions which even to-day are difficult of access. Altogether, they published data on the compositions of the oils of some 300 species of plants, as well as accomplishing a large quantity of phytochemical work on such substances as gums, resins, oleo-resins, kinos, and plant products of all sorts. Smith's chemical work was particularly meritorious when, as the late Professor John Read has pointed out, it was prosecuted in spite of inadequate preliminary training (he was 40 years of age before he published his first paper in organic chemistry), and complete isolation from any centre of organic chemical activity. It is true that organic chemistry had been taught at the University of Sydney since the eighties, but it was on a very modest scale, and the Chair in that discipline was not established until 1913. In fact, many of Sydney's early organic chemists were trained in Smith's own classes in the Museum, held on behalf of the Sydney Technical College from 1898 to 1911. Despite these disadvantages, Smith was nevertheless able to isolate and characterize from the oils of the *Eucalyptus* species alone some 40 different compounds, including some new to science. The genus *Eucalyptus* was not the only plant group whose volatile oils were examined by these workers. They carried out a systematic examination of the conifers of Australia, from one of which, *Phyllocladus rhomboidalis* or "celery-top pine" of Tasmania, they isolated the new compound phyllocladene (IV), a diterpene, and examined the oils of species from a number of genera such as *Melaleuca, Darwinia, Boronia* and *Prostanthera.* Smith retired from his position at the Museum in 1920, but continued to work until his death in 1924, enjoying the hospitality of the laboratory of



IV. Phyllocladene.

Professor John Read at the University of Sydney. Baker retired at approximately the same time as his colleague, but survived him by many years, attaining the age of 86 before his death in 1941.

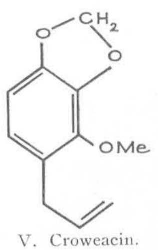
Between the Wars: 1920-1945

The year 1920 may be held to mark the beginning of the third period of essential oils research in this review, and may be considered as extending to the end of the Second World War. This third period differed from the two preceding by the simultaneous activity of several schools of research in this field: A. R. Penfold and the late F. R. Morrison succeeding Baker and Smith in Sydney; Professor T. G. H. Jones and his co-workers at the University of Queensland; and the late Professor A. K. Macbeth at the University of Adelaide, together with his associates P. A. Berry, T. B. Swanson and R. G. Cooke. Towards the end (1934-1945) of this period, E. M. Watson of Perth Technical College, joined by G. E. Marshall, carried out an examination of the oils of 13 Western Australian species of *Eucalyptus,* a group in this genus which by reason of distance had largely been neglected by the workers of the eastern States and which had been but briefly touched on locally by Phillips in 1923. In addition to the major schools, workers in the Organic Chemistry Department of the University of Sydney over the period 1920-1945 made valuable contributions to the chemistry of compounds isolated from the flora of the Commonwealth.

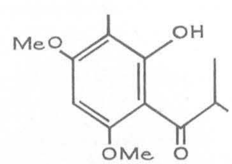
Consideration of this third era, 1920-1945, may well commence with the work of Penfold and Morrison in Sydney, partly because it was a continuation, modernization and extension of the work of Baker and Smith in the same institution; and partly because of their breaking new ground in their recognition of the phenomenon of chemical variation within a species, an observation which cast doubt on the validity of the chemotaxonomic views of their predecessors at the Museum. This aspect will be dealt with later in this chapter.

The work of Penfold and Morrison was an advance in this field in Australia, inasmuch as they introduced fractional distillation *in vacuo* as a regular procedure in the resolution of an oil into its components; Smith only roughly resolved his oils into fractions of mixed composition by crude fractional distillation at atmospheric pressure, with the result that he could present only a very approximate idea as to components present and their percentages. Penfold and Morrison, on the other hand, by careful fractional distillation at pressures reduced to 5 to 20 millimetres of mercury, were able to achieve better separations of fractions having a minimum of chemical alteration: Smith's fractions must have been badly affected by the high temperatures of distillation of these liquid mixtures whose components boil at atmospheric pressure over the range of about 150° to 400° C. Furthermore, by the use of a greater variety of newer reagents, Penfold and Morrison were able to prove the presence of more compounds by derivative formation, and thus give a more accurate account, qualitatively and quantitatively, of oil compositions.

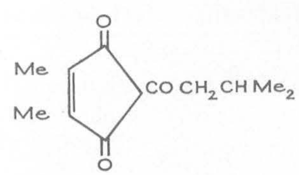
These two workers gave in this way a fairly complete picture of the compositions of the oils of some 60 different species from a number of different genera, in the course of which they isolated many new compounds which attracted world-wide interest amongst organic chemists. The structures of the molecules of some of these compounds are shown below:



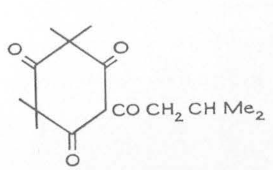
V. Croweacin.



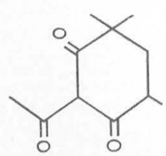
VI. Baeckeol.



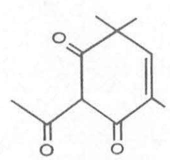
VII. Calythrone.



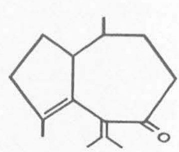
VIII. Leptospermone.



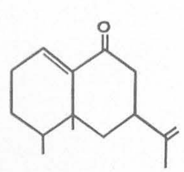
IX. Angustione.



X. Dehydroangustione



XI. Zierone.



XII. Eremophilone.

It was Penfold also who in 1921 finally established the position of the double bond in the piperitone molecule, and to him also must be given much of the credit for the introductions of the oil of the foliage of *Melaleuca alternifolia,* one of the paper-barked "tea trees" of the north coast of New South Wales, as a germicide during the mid-twenties, a position which it still holds in commerce.

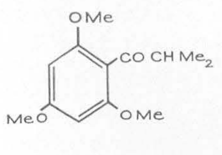
An important aspect of the work of Penfold and Morrison arose from their observations on chemical variation in oil compositions within a species. Baker and Smith insisted that a given species of plant would show a constancy of oil composition over its entire range of distribution, and that this chemical character was in fact of equal value to any other in establishing the taxonomic position of the plant. Indeed, they even went so far as to erect taxa solely on chemical evidence (for example, their "*Eucalyptus phellandra*" and "*E. australiana*", now recognized only as chemical variants within *E. radiata*), and when they observed that one of the chemical variants of *E. dives* produced an oil identical in composition with that of "*E. australiana*", but differing markedly from the *E. dives* with which they were familiar, they named it "*E. australiana* variety *latifolia*" to overcome the awkward fact that it was morphologically very different from "*E. australiana*".

Penfold and Morrison made a useful contribution to this aspect of essential oil chemistry by showing that chemical variation, sometimes very pronounced, could exist between oils from individual plants. Indeed, as early as 1922, Penfold had published his "Observations respecting some essential oils from *Leptospermum liversidgei*", in which he noted that, whereas the foliage of this species from some sites yielded oils containing citronellal, other occurrences of the shrub yielded oils distinguishable by their containing citral, no citronellal being detected. In 1924, Penfold and Morrison were re-examining the leaf oils of *Eucalyptus piperita,* collecting from different provenances, and in the same year published data to show that although trees growing in the vicinity of Port Jackson gave leaf oils in yield of from 2·0 to 2·5 per cent and containing 40 to 50 per cent of piperitone, foliage from the trees of the same species found growing in other places yielded only 0·6 to 0·8 per cent of oil containing very little piperitone, but rich in eudesmol and cineole, substances not observed by them in the Port Jackson oils. Three years later they commenced publishing data on the leaf oils of *E. dives,* the "broad-leaved peppermint" of the Great Dividing Range of New South Wales and Victoria, to show that four chemical categories could be distinguished in this species. From the twenties onward, Penfold and Morrison demonstrated numerous instances of chemical variation within species, not only in *Eucalyptus,* but in other genera, and not only from the one family, but from other families, in *Boronia* and *Geijera* for example, in the family Rutaceae. As the evidence accumulated, it became clear that environmental differences could not be linked with these variations, and that the chemical composition of an oil must be genetically determined.

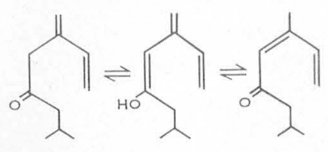
The recognition of this phenomenon has had two consequences. Firstly, it has attracted the interest of geneticists and chemotaxonomists, whose reactions will be dealt with later, and secondly it has materially assisted the essential oil industry by directing attention to those forms of a species which yield commercially-valuable oils, and to the areas in which they may be found. For example, in the case of *Eucalyptus dives* just quoted, one form growing in certain areas of New South Wales is distilled for an oil rich in piperitone for menthol synthesis; other areas were pointed out in which the same species (the so-called "variety C") is equally useful commercially, but as a source of a cineole-rich oil for pharmaceutical purposes. In Victoria, however, the various forms tend to grow intermingled and commercial distillation of this species is rendered difficult in that State. Even this difficulty, however, was overcome in the case of the "broad-leaved tea-tree", *Melaleuca quinquenervia,* distilled during the nineteen-fifties for an oil rich (*ca.* 90%) in the aliphatic sesquiterpene alcohol, nerolidol. The high price commanded by this oil and the difference in odour from the oil of the commercially-worthless variants growing adjacent led to successful commercial distillation until cheaper synthetic nerolidol appeared on the market.

Attention should now be turned to the other schools flourishing contemporaneously in this second period of research; to that led by Jones at the University of Queensland, and that led by Macbeth at the University of Adelaide.

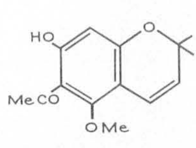
Jones and his co-workers, especially F. N. Lahey, worked on the compositions of the oils of the flora of Queensland, and during the years 1923 to 1945 the oils of more than 20 different species were examined from such genera as *Daphnandra, Agonis, Mentha, Santalum, Baeckea, Eriostemon, Eremocitrus, Melaleuca, Backhousia* and *Cinnamomum.* Interesting new compounds were discovered, for example, from the leaf oil of the stunted "stringybark", *Eucalyptus conglomerata,* conglomerone (XIII) was isolated. From "stinking Roger", a naturalized



XIII. Conglomerone.



XIV. Tagetone.



XV. Evodionol.

weed of the genus *Tagetes* was isolated tagetone, an unsaturated aliphatic ketone depicted by the tautometric system shown (XIV). The structure of the molecule of evodionol (XV) from *Euodia littoralis* was elucidated by Lahey. Jones and Harvey in 1933 re-opened the question of the oils of one of the "broad-leaved tea-trees", *Melaleuca quinquenervia* (referred to in earlier publications as *M. viridiflora*), left in a confused state in the literature, both botanically and chemically, by Baker and Smith twenty years earlier. The Queensland workers were able to show that Smith's "melaleucol" was the aliphatic sesquiterpene alcohol nerolidol (XVI), and, shortly afterwards, by examining the oils from single trees within a population of the species, Jones and Haenke were able to demonstrate the existence of chemical

XVI. Nerolidol.

variation within the species. From one of these forms they isolated the new solid sesquiterpene alcohol, viridiflorol. During the years of the Second World War, work proceeded on tagetone, on the synthesis of conglomerone, and on α-phellandrene and its monohydrochloride. Hancox and Jones also described a new derivative, the chloronitrosite, for 1-terpinen-4-ol.

To Macbeth's school at Adelaide we are indebted for an extension to our knowledge of the phellandrenes, particularly of their isomeric nitrosites. These workers also settled the structure of the nine-carbon terpene ketone, cryptone, originally isolated by Smith and thought by him to be an aldehyde. In 1940, Cooke, Macbeth and Swanson provided final proof of the structure of the terpene aldehyde, phellandral, with which cryptone commonly occurs associated in oils of *Eucalyptus* species, and, in addition, a considerable number of papers on alicyclic compounds related to the terpenes was published by this active group in the *Journal of the Chemical Society* in London. More detailed knowledge of the composition of the oil of the Kangaroo Island "mallee", *E. cneorifolia,* distilled commercially at that time in large quantities, was first obtained through the investigations at Adelaide. P. A. Berry published many useful papers on such subjects as the preparation and characterization of certain terpene tetrabromides, the action of sodium sulphite on cryptone, and the action of bromine on β-phellandrene. He also worked on the composition of the oil of *E. conglobata* variety *anceps,* and conducted experiments on the seasonal variations in the oil of *E. cneorifolia.* Berry, in fact, may be regarded as the foundation member of the group, since his first essential oil paper appeared in 1922.

Work at the University of Sydney during this period was earlier mentioned. This may be considered as tracing its origins back to Professor Sir Robert Robinson and Professor John Read, the first and second occupants respectively of the Chair of Organic Chemistry, and thence in turn to Smith. Robinson worked jointly with Smith on phytochemical researches, and Read's long interest in terpene chemistry undoubtedly was stimulated by his early contact with Smith and the substances he was isolating. In fact, in delivering the 19th Streatfeild Memorial Lecture in 1936, Read said of their early association: "I was privileged to collaborate with him in some of this work, and between 1919 and 1924 (the year of his death) we completed 15 joint publications. To F. W. Streatfeild I owed much in my first years as a student of organic chemistry; to H. G. Smith the debt was equally great during my first years in a chair of organic chemistry; although they were unknown to each other in life, they are joined in my grateful memories." Read's work on piperitone, phellandrene, the menthones, thujones and related substances is now a classic contribution to organic chemistry, and undoubtedly his influence lingered on in his Department long after he left for St. Andrews in Scotland. V. M. Trikojus, for example (now at the University of Melbourne) and the late D. E. White made valuable additions to our knowledge of the constituents of the wood oil of cypress pine (*Callitris* spp.) (a field carried further by Reuter at the Sydney Technical College). They settled the structure of the molecule of australol, the phenol isolated by H. G. Smith from oils of *Eucalyptus.* A. J. Birch, now recently come to the Australian National University from Manchester, began his life-long interest in terpene chemistry in the same Department at Sydney, his first work being on α-phellandrene and on thujene.

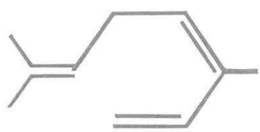
Post-War Years: 1945-1967

It remains now only briefly to review work since the end of the Second World War, from 1945 to the present; this period thus constituting the fourth and contemporary phase.

The University of Queensland in Brisbane and the Museum of Applied Arts and Sciences in Sydney continued to be active centres of research in the chemistry and biology of the essential oils of Australia. At the University of Sydney, until he left for Manchester, Professor A. J. Birch led an active school during the fifties in the chemistry of natural products, including essential oil constituents, and with particular emphasis on biosynthesis. In the more westerly part of the continent, the centre of gravity moves from Adelaide to the University of Western

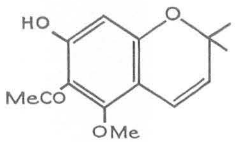
Australia to which D. E. White had gone, now succeeded after his untimely death by P. R. Jefferies. Dr. A. Blumann, who had worked in his early years with Wallach, was active in terpene chemistry before the Second World War, and, in association with the late H. V. Marr, was instrumental in establishing the synthetic menthol industry in Perth, using piperitone from *Eucalyptus dives* oil as the starting point. Blumann has worked actively during the present period of review with the group at the University of Western Australia.

Attention will first be directed to the contributions from the Queensland school, now under the active leadership of M. D. Sutherland who, significantly enough, came to Brisbane shortly after the war from Professor L. H. Briggs at Auckland, bringing with him experience from that well-known school of natural products research. Sutherland was the first in this field in Australia to recognize that the resolution of volatile plant oils into their components by fractional distillation *in vacuo*, as currently practised, left much to be desired, and one of his earliest activities was the introduction of high-efficiency fractionating columns. At the same time he called attention to the unsatisfactory state of knowledge of the physical properties of even the commonest terpenes. Hitherto these had been known only in impure states, and he published data for the physical constants of such

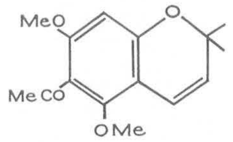


XVII. Ocimene.

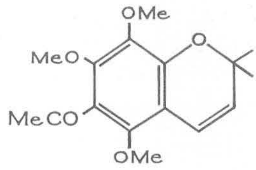
compounds as α- and β-phellandrene, myrcene, etc., which for the first time were prepared in a state approaching purity. Sutherland also introduced the idea into essential oil chemistry of plotting on a curve density against refractive index for each successive fraction collected during a fractional distillation. The positions of these points could then be related to the fixed points for the pure substances. In addition, by the use of coloured derivatives (phenylazophenyl-urethanes) of terpene alcohols chromatographed on alumina columns, Sutherland was able to give some insight into the hitherto unsuspected complexity of essential compositions in the days preceding gas chromatography. On the structural side, the Queensland school entered the isopropenyl-isopropylidene controversy which had for so long raged amongst terpene chemists, and in 1952 Sutherland published evidence to show that ocimene must have the structure shown in (XVII). The investigations of Jones, Lahey and the late S. E. Wright on various naturally-occurring chromenes continued, and this series of related compounds has now been established as follows:



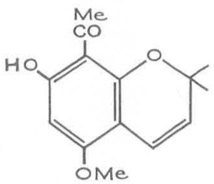
XVIII. Evodionol.



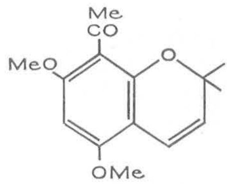
XIX. Methyl evodionol.



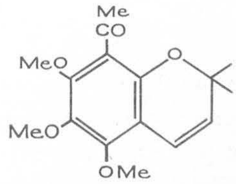
XX. Evodione.



XXI. alloEvodionol.

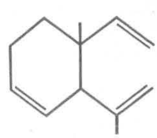


XXII. Methyl *allo*evodionol.

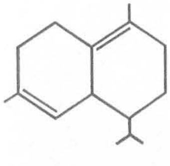


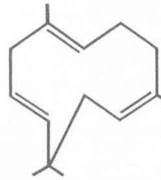
XXIII. *allo*Evodione.

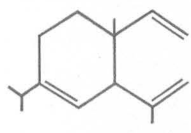
Sesquiterpene chemistry has also been an important contribution from this group. The hydrocarbon geijerene, originally isolated by Penfold from the leaf oil of *Geijera parviflora* ("wilga"), was shown to be the racemic form of the substituted cyclohexene shown in (XXIV).


XXIV. Geijerene.

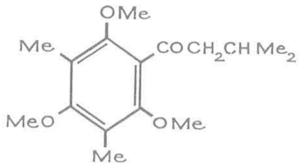
"Dysoxylonene" from the oil of the wood of the rain-forest tree *Dysoxylon fraseranum* or "rosewood", also first isolated by Penfold, was shown to be δ-cadinene (XXV). Other important structural work was on humulene (XXVI), δ-elemene (XXVII) and zierone (XI), as well as on the sesquiterpene alcohol of *Myoporum crassifolium* wood oil, anymol, in collaboration with the Sydney workers.


XXV. δ-Cadinene.


XXVI. Humulene.

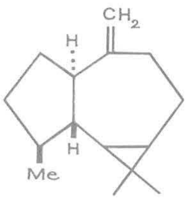

XXVII. δ-Elemene.

In Western Australia, the small but active group, initially numbering amongst its members D. E. White and A. Blumann, is ranging freely over the chemical products of the western flora, including the volatile oils. Safrole and eugenol methyl ether were found by P. R. Jefferies and E. W. Della as the main components of *Eriostemon longifolia* oil, and the new compound torquatone (XXVIII) was isolated from the oils of some western species of *Eucalyptus,* and was

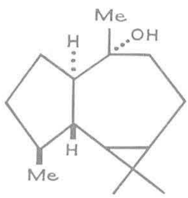


XXVIII. Torquatone.

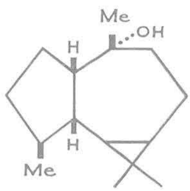
shown by Bowyer and Jefferies to have the structure above, which they confirmed by synthesis. Studies in the stereochemistry of the sesquiterpenes aromadendrene (XXIX), globulol (XXX) and ledol (XXXI)



XXIX. Aromadendrene.



XXX. Globulol.



XXXI. Ledol.

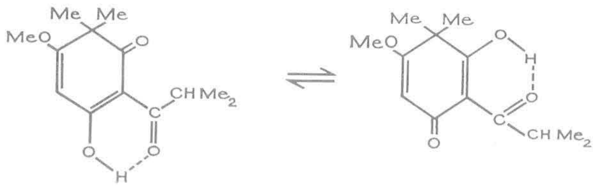
were made by Jefferies and White and co-workers who proposed the molecular configurations shown. Blumann has demonstrated his continuing interest in this field, and his association with the University, by his work on the oxides of α-phellandrene, on carveol, on cuminyl alcohol and 1-terpinen-4-ol from *Eucalyptus dives* oil, and on globulol from *E. gongylocarpa* bark oil.

At the University of Sydney, Professor A. J. Birch occupied the Chair of Organic Chemistry during the early fifties, and he and his students carried out work on a number of essential oil components whose molecular structures were regarded as not yet established. In this series of studies, Birch pointed out that an hypothesis of the biogenesis of many natural products by the "head-to-tail" linkage of acetate units could be used, like the isoprene rule, in favourable cases to indicate the most probable of the numerous possible structures suggested by the purely chemical evidence. Some of the compounds thus examined were "macropone" (4-isopropylsalicylaldehyde) from the oils of some *Eucalyptus* species; angustione, dehydroangustione and angustifolionol from *Backhousia angustifolia* oil, and the β-triketones tasmanone, calythrone and xanthostemone.

Work at the Museum of Applied Arts and Sciences in Sydney in the post-war years centred on a new phase in that the genetics of oil-bearing species was considered, and plantations were established where the progeny of these species could be studied, and where other biological experiments could be carried out. These early studies were initiated by S. Smith-White, now Professor of Biology at the University of Sydney, and by L. H. Bryant, now Deputy Chief of the Division of Wood Technology of the Forestry Commission of New South Wales. Smith-White was succeeded in the botanical work by J. L. Willis, the present Director of the Museum, in 1948, whilst the chemical work had been taken over by H. H. G. McKern in 1945 when Bryant resigned to go to the Forestry Commission.

Traditionally, a school of essential oil chemistry occupies itself with the elucidation of the compositions of the oils of hitherto unexamined species, or re-examining oils where it is considered that existing knowledge is inadequate. The isolation of new compounds poses problems in the elucidation of their molecular structures and conformations, and perhaps associated synthetic work. There were several connected reasons why this traditional pattern of research was extended at the Museum in a biological direction. One was the phenomenon, now so well established, of profound chemical differences within the oils of some species, and the next obvious step was to test this behaviour in different environments and for successive generations. A further use to which these plantations were put was, before publishing oil composition data, to test the original experimental plants for freedom from hybridism, a factor which may have a large chemical effect without detectable morphological effect in the experimental material. Thirdly, genetic studies were necessary to gain information useful to the establishment of commercial plantations of oil-bearing plants. As it costs the same to establish and maintain a plantation of trees of poor oil yield and low quality as for those of superior yield and quality, it was decided to investigate to what extent these two characters were under genetic control. Willis was able to show that they were, in fact, genetically determined, and that careful seed selection from élite parent plants was advisable for this purpose. B. E. J. Small has been examining such questions as response to nutrients, optimum spacing of plants, frequency and method of harvesting foliage and other related matters. This has been stimulated by the severe competition which the Australian industry, still based on natural occurrences of these economically-valuable species, has been receiving in recent years from the production of other countries which have been more alert to establish plantations of species originating in this country. *Eucalyptus dives* oil, once produced in large quantity as a source of piperitone, is now imported from South Africa from plantation trees.

This research group in Sydney thus took the view that volatile oils are fundamentally a biological problem, but in which chemistry is a major research tool. The purely chemical side, however, has not been neglected, and using the newer instruments, the earliest of which to receive application in the post-war years were gas chromatography and infra-red spectroscopy, the compositions of new oils have been described, and attention has been drawn to further instances of chemical variation within a species. New compounds have been discovered; for example, agglomerone, a solid β-triketone occurring in the leaf oils of some "stringybark" species of *Eucalyptus,* which was shown by Hellyer to possess the enol structure (XXXII) shown:



XXXII. Agglomerone.

One of the distinguishing features of the work of the pioneers at the Museum, Baker and Smith, was their interest in chemotaxonomy. After a lapse of interest for a generation, this subject has in recent years received great attention from phytochemists the world over, and the significance of the volatile oils in this context has been recently reviewed by McKern.* In this paper he refers to the problem raised by chemical variation in a species in attempting to co-relate chemical characters with the taxonomic position of a plant; recent work at the Museum, however, suggests that these chemical variants within a species are quantitative in nature only, and not qualitative, as previously thought. Refined modern techniques are showing that these apparently profound differences are due merely to enormous differences in concentration of a given constituent, from perhaps a few parts per million in the oil of one plant to 80 or 90 per cent in that of an adjoining plant. These great differences in levels of concentration are nevertheless under genetic control, and hence are of scientific interest and of commercial importance.

This, then, concludes a brief retrospect of over a century of continuous endeavour by scientists working in this country on a flora of remarkable chemical richness. Unfortunately, the labourers have at all times been too few, and the species numerous; much therefore remains to be done. However, the lessons of the past point the way to

* H. H. G. McKern: "Volatile Oils and Plant Taxonomy", *J. & Proc. Roy. Soc. New South Wales,* 98 (1965) 1-10.

fresh endeavours: the compositions of the oils of uninvestigated species must be examined and any chemical variants defined; and the structures of the molecules of new compounds encountered must be determined. Biosynthetic pathways are still of interest, and the significance of volatile oil production to the plant is still not known. Chemotaxonomy is a live question at present, and more chemical data are urgently needed for those working in this field. In spite of the progress of synthetic chemical industry, many chemicals are still more cheaply supplied to industry from natural sources, and the economic application of these plants should receive encouragement—Bosisto would be delighted by the tremendous increase in our knowledge of the chemistry of the oils of the Australian flora, but disappointed by lack of enterprise in cultivating them, and by the initiative in this respect passing to other nations. Nevertheless, in spite of a small scientific population, the Australian record in natural products chemistry would make a monograph of considerable size, in which the chapter on the volatile plant oils would form a prominent part.