<table>
<thead>
<tr>
<th>Title</th>
<th>The Chemistry on Diterpenoids in 1965</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Fujita, Eiichi</td>
</tr>
<tr>
<td>Citation</td>
<td>Bulletin of the Institute for Chemical Research, Kyoto University (1966), 44(3): 239-272</td>
</tr>
<tr>
<td>Issue Date</td>
<td>1966-10-31</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/2433/76121">http://hdl.handle.net/2433/76121</a></td>
</tr>
<tr>
<td>Type</td>
<td>Departmental Bulletin Paper</td>
</tr>
<tr>
<td>Textversion</td>
<td>publisher</td>
</tr>
</tbody>
</table>
The Chemistry on Diterpenoids in 1965

Eiichi FUJITA*
(Fujita Laboratory)

Received June 20, 1966

I. INTRODUCTION

Several reviews on diterpenoids have been published. Last year, the author described the chemistry on diterpenoids in 1964 in outline. The present review is concerned with the chemical works on diterpenoids in 1965.

The classification consists of abietanes, pimaranes, labdanes, phyllocladanes, gibbanes, diterpene alkaloids, and the others.

II. ABIETANE AND ITS RELATED SKELETONS

Lawrence et al. isolated palustric acid (2) from gum rosin. The selective crystallization of its 2,6-dimethylpiperidine salt, which precipitated from acetone solution of the rosin, from methanolacetone (1:1) was effective for isolation.

The four conjugated dienic resin acids, namely, levopimaric (1), palustric (2), neoabietic (3), and abietic acid (4) were treated with an excess of potassium tert-butoxide in dimethyl sulfoxide solution at reflux temperature (189°) for 2 minutes. All four solutions then exhibited a single major peak in their U.V. spectra characteristic of abietic acid. The acids were allowed to react with diazomethane and the reaction mixtures were analyzed by g.l.c. The major result of the base-catalyzed

* 藤田栄一
*2 See references cited in the review published last year by the author.
reaction was the isomerization of the resin acids to abietic acid, similar to their behavior in acid solution.

The N.M.R. spectra of the derivatives of dehydroabietic (5) and podocarpic acid (6) and of their 5-epimers were discussed by Wenkert et al. A correlation of the chemical shifts of methyl groups and other side chains was presented. The stereochemistry of the conformationally flexible A/B cis compounds was analyzed.

Oxidation of abietic acid (4) with selenium dioxide furnished dehydroabietic acid (5) and a hydroxyabietic acid which had been assigned formula 12-hydroxyabietic acid by Fieser and Campbell. The structure of the latter was revised to 9-hydroxyabietic acid (7) by Herz and Wahlborg. The assignment was based on spectroscopic evidence and its conversion to $\Delta^{7,10}$-abietadienoic acid (8) which was in turn synthesized from $\Delta^{7,10}$-abietenoic acid (9). In the course of this work, an entry into the pseudoabietic acid series has been effected and the stereochemistry of the various lactones, e.g. 10, 11, and 12, belonging to this series has been elucidated. The $\gamma$-lactone 11 is unstable and is quickly isomerized to $\delta$-lactone 12 which then yields an equilibrium mixture of 10 and 12.
Herz et al. treated levopimaric acid (1) with hypochlorous acid in a basic solution to give 12ß-hydroxyabietic acid (13). The latter was established by an independent synthesis from levopimaric acid peroxide. Hydrogenation gave two dihydro derivatives, 14 and 15, and a tetrahydro derivative 16. The O.R.D. curves of 12-keto 8ß-H-abietanes were discussed.

The Diels-Alder reaction of levopimaric acid (1) with formaldehyde yielded adduct 17 in high yield. The cleavage of the ether linkage of compound 17 was effected in acidic condition to give 12-hydroxymethylabietic acid (18). The latter on reduction with lithium aluminum hydride gave diol 19, which was in turn derived from adduct 17 via 20 by reduction and treatment with acid.
Wenkert and Mylar9) carried out a reduction of the enol lactone 21 with sodium borohydride and got a new hydroxylactone 22. Jones oxidation of this compound yielded a new ketolactone 23 whose sodium borohydride reduction reyielded the hydroxylactone while calcium-ammonia reduction, followed by hydrogenation, gave 5-isodehydroabietic acid (24).

On the basis of the N.M.R. analysis, Narayanan and Linde10) proposed the A/B trans stereochemistry 25 for salvin (=carnosic acid), whose plain structure had been proposed by Linde.11) They also proposed the structure of picrosalvin (=carnosol) including the absolute configuration as formula 26; the conversion of salvin to picrosalvin had been carried out. These suggestions are completely identical with the conclusions published already by Wenkert et al.12)

Russian workers13) had reported the presence of an alkaloid, rosmaricine, in *Rosmarinus officinalis*. Wenkert et al.14) isolated rosmaricine from the leaves of the plant according to the method of Russian workers, and determined its structure as formula 27. However, when rosemary leaves were extracted without the use of ammonia, no rosmaricine or other basic substances could be detected among the plant constituents. Contrastingly, exposure of the same plant extracts to ammonia and air led to the production of rosmarine. Exposure of the extracts to sodium carbonate solution yielded no rosmaricine. A further detailed investigation resulted in a suggestion that rosmaricine (27) and carnosol (=picrosalvin) (26) must be artifacts from carnosic acid (=salvin) (25).

Dutta et al.15) synthesized bicyclic ketoacid 28, the stereochemistry of which was established by its conversion to methyl 5-epidesopropyldehydroabietate (29). They also recognized that the heating of compound 30 with palladium on charcoal gave methyl desopropyldehydroabietate (31) in poor yield. They reached a complete agreement with Spencer's conclusion.16)
Cambie et al. investigated O.R.D. and C.D. curves of α-bromo derivatives of cyclohexanones conjugated to an aromatic ring; the α-bromo derivatives of 7-oxototarol (32), sugiol (33), 7-oxo-podocarpic acid (34), and 7-oxo-dehydroabietic acid (35) were studied.

In a study of synthesis of the parent chromophore in a triterpenoid, pristimerin, Hill et al. attempted the reduction of methyl 0-methyl-\(\Delta^{(6)}\)-7-oxo-podocarpate (36) to deoxo compound (37), but they could not get a good result.

Dehydroabietylamine was advantageously used to separate (−)-enantiomorph of racemic α-phenoxypropionic acid and D-(−)-enantiomorph of racemic α-benzyloxy carbonylanilino phenylacetic acid. Taylor et al. investigated a lead tertaacetate oxidation of 14-isopropylpodocarpa-8,11,13-triene-6α,13-diol 13-monoacetate (38); they got a cyclic ether (39), in which the ring A has a boat form.
Huffman and Arapakos\textsuperscript{21} synthesized tricyclic steroid analogs 40 and 41 from dehydroabietic acid (5), and gave a discussion on their stereochemistry. Grelach\textsuperscript{22} isolated Solidago-diterpene A from the root of Solidago canadensis and S. gigantea, and assigned structural formula 42 on the basis of spectral and chemical evidences.

\[
\text{OH} \quad \text{O} \quad \text{I17} \quad \text{I1} \quad \text{I} \\
\text{H}_3\text{COOC} \quad \text{H} \quad \text{OH}_3\text{COOC} \\
\text{(42)} \quad \text{(43)} \quad \text{(44)}
\]

Tahara et al.\textsuperscript{23} derived methyl 6\textbeta,15-epoxy-enantiopodocarpa-8,11,13-trien-10-oate (43), methyl 6\alpha,17-epoxyenantiopodocarpa-8,11,13-trien-16-oate (44), and their derivatives from abietic acid (4). These compounds are useful as potential intermediates for the syntheses of the other natural diterpenoids.

The reactions between p-nitroperbenzoic acid and certain Diels-Alder addition compounds in the diterpene series, e.g. 45 and 46, were investigated.\textsuperscript{24} Cis opening of an epoxy group was also observed.

Girotra and Zalkow\textsuperscript{25} got a mixture of dienes 48 and 49 from pyrolysis of diacetate 47 which was derived from podocarpic acid (6). Subsequent Diels-Alder reaction with maleic anhydride yielded two kinds of crystalline adducts 50 and 51.

Zalkow et al.\textsuperscript{26} examined the O.R.D. of such types of compounds as 52 and 53.
The Chemistry on Diterpenoids in 1965

They\textsuperscript{27} also carried out ozonolysis of methyl maleopimarate (45), obtaining compounds 55 and 56 in addition to the known product 54.\textsuperscript{28} The revised formulas given by them to the former two compounds were not in agreement with those proposed by Ruzicka et al.\textsuperscript{29,30}

\[
\begin{align*}
(54) & \quad \text{COOCH}_3 \\
(55) & \quad \text{COOCH}_3 \\
(56) & \quad \text{COOCH}_3
\end{align*}
\]

Attempted epoxidation\textsuperscript{27} by trifluoroperacetic acid of trimethyl maleopimarate (57, \textsuperscript{COOCH}_3: \beta) and isomeric trimethyl fumaropimarate (57, \textsuperscript{COOCH}_3: \alpha) gave a hydroxy lactone 58 and epoxy triester 59, respectively.

\[
\begin{align*}
(57) & \quad \text{H}_3\text{COOC} \\
(58) & \quad \text{H}_3\text{COOC} \\
(59) & \quad \text{H}_3\text{COOC}
\end{align*}
\]

Ayer and McDonald\textsuperscript{31} got acid 61, diene 62, and two kinds of lactones 63 and 64 by a lead tetraacetate oxidation of methyl fumaropimarate (60). They also described a speculation on their mode of formation.

\[
\begin{align*}
(60) & \quad \text{H}_3\text{COOC} \\
(61) & \quad \text{H}_3\text{COOC} \\
(62) & \quad \text{H}_3\text{COOC} \\
(63) & \quad \text{H}_3\text{COOC} \\
(64) & \quad \text{H}_3\text{COOC}
\end{align*}
\]

Karanatsios and Eugster\textsuperscript{32} investigated the structure of coleone A, one of the leaves pigments from \textit{Coleus igniarius} (Labiatae), and assigned the structural formula
Eiichi Fujita

65 to the substance on the basis of the results of various chemical reactions and spectroscopic data.

They considered the biogenesis of coleone A as shown in Scheme 1, and seeked for a phenolic precursor in the same plant source. But, they could not isolate any phenolic substance.

III. PIMARANE AND ITS RELATED SKELETONS

Edwards et al.33 provided an evidence on the epimeric character of C-13 substituents of pimaric acid (66) and isopimaric acid (67). They also gave an evidence of nuclear double bond location in isopimaric acid. Thus, the structure and stereochemistry of isopimaric acid were determined as 67.

Wenkert et al.42 discussed on N.M.R. spectra of pimaric acid (66), isopimaric acid (67), and sandaracopimaric acid (68).

ApSimon et al.34 proved that tetrahydro derivatives of pimaric acid (66), isopimaric acid (67), and sandaracopimaric acid (68) have trans-anti-trans fused skeletons, and discussed the implications of this observation.

Both of isopimaric acid (67) and pimaric acid (66) on ozonolysis give a same ketocarboxylic acid 69. Enzell and Thomas35 investigated ozonolysis and perphthalic acid oxidation on compounds having a double bond between C-7 and C-8.

* See also ref. 85 (Section V).
and observed the similar anomalous ozonolyses; araucarolone diacetate (70) on ozonolysis followed by reduction with zinc and acetic acid gave as main product an epoxide (65%) together with a small yield of the ketoaldehyde 71 (20%). To demonstrate the structure of the epoxide, araucarolone diacetate was treated with monoperphthalic acid in ether. The product was a mixture of four epoxides, one of which was identical with the ozonolysis epoxide. Structural formula 72 was assigned to this epoxide on the basis of analysis, infrared spectrum, and N.M.R. data. They studied also the action of ozone and of monoperphthalic acid on the simpler analog, 16-norpimar-7-ene (73). From the results obtained, they discussed on the reaction route for this anomalous ozonolysis.

Herz and Mirrington synthesized (−)-rimuane (79) from isopimaric acid (67); lactonization of dihydro derivative 74 of the starting material by the method of Edwards and Howe to compound 75 and hydrolysis of the latter with potassium hydroxide in refluxing diethylene glycol afforded acid 76. Subsequent lithium aluminum hydride reduction and catalytic hydrogenation under the addition of a trace of perchloric acid gave saturated alcohol 77. Oxidation of 77 with Jones reagent at 0° yielded aldehyde 78 which afforded (−)-rimuane (79) when subjected to Huang-Minlon reduction.

The same authors investigated the stereochemistry of the tetrahydropimaric acids. Hydrogenation of dihydropimaric acid (80) at 20° and at atmospheric pressure gave a tetrahydropimaric acid, which had been given the suggestion that this might be trans-anti-trans isomer 81 by a French group. The suggestion was now
clarified to be correct by an unambiguous synthesis by the American group.

Herz and Mirrington\(^4\) also carried out the conversion of pimaric acid (66) to (-)-13-\textit{epi}-rimuane (82). The route is similar to that in which (-)-rimuane (79) was derived from isopimaric acid (67). (See above.)

Grant and Munro\(^4\) elucidated, on the basis of the several chemical evidences and N.M.R. data, the structure of compound B, a diterpene diol from heartwood extractives of \textit{Dacrydium colensoi} to be sandaracopimaradiene-3\(_8\),19-diol (83).

Connolly, Kitahara et al.\(^4\) showed that keto-aldehyde 85, the ozonolysis product of dolabradiene (84), is different from keto-aldehyde 87 derived from erythroxydiol Y (86), and that monoketones 88 and 89, partial reduction products of keto-aldehydes, are enantiomeric each other. Thus, a further evidence on the same configuration of C-13 in dolabradiene (84) and erythroxydiol (86) was presented.

Whalley et al.\(^4\) gave an active demonstration for the location of the carboxy group in rosenonolactone (90), a diterpenoid metabolite from \textit{Trichothecium roseum}; reduction by the Clemmensen process of 10-hydroxy-rosan-16-oic \(\gamma\)-lactone (91) gave rosan-16-oic acid (92), which was converted by way of the ester 93 into rosan-16-ol (94). Dehydrogenation of the alcohol with phosphorus pentachloride gave a halogenated hydrocarbon which, after successive treatment with boiling quinoline and then sodium, was dehydrogenated to yield 1-ethyl-7-methylphenanthrene (95).
Further examination of rosic acid (96), together with an investigation of the isomeric triols obtained by reduction of dihydrorosenono- and dihydroisorosenono-lactone, substantiated the structure 90 of the metabolite and enabled the relative stereochemistry of rosenono- (90) and isorosenono-lactone (97) to be defined.

The absolute configuration of C-13 in rosenono- and rosolo-lactone was also established by Whalley et al.44; degradation of (+)-5-ethyl-2,5-dimethylcyclohexanone (98) derived from ring C of dihydrorosenonolactone gave (+)-3-ethyl-3-methyladipic acid (99).

IV. LABDANE AND ITS RELATED SKELETONS*

Weissmann and Bruns45 isolated a hydroxyditerpenecarboxylic acid from the resin of Araucaria imbricata (A. araucana) and reported its identity with acid 100 which was isolated by Chandra et al.46 from A. imbricata. But later, the same authors47 by themselves denied the foregoing identity and reported the isolation of acetoxy acid 101, hydroxy acid 102, acetoxy aldehyde 103, hydroxy aldehyde 104, and diol 105.

Lawrence et al.48 showed the identity of elliotinoic acid, which is isolated from the oleoresin of the slash pine (Pinus elliottii), with communic acid (106), and also the identity of elliotinol isolated from the same plant source with compound 107, which up to that time had not been observed in nature, but had been obtained only as a reduction product of methyl comminate.

* See also ref. 143 (Section VIII).
Norin compared N.M.R. and U.V. spectra of methyl communate with those of trans-ocimenes and recognized their similarity. Thus, he assigned the trans configuration to the side chain as shown in formula \( \text{108} \).

Graham and Overton proved that eperuic acid and labdanolic acid are antipodal apart from C-8 and C-13, as shown in formulas \( \text{109} \) (eperuic acid) and \( \text{110} \) (labdanolic acid). The trans-syn-configuration previously assigned to eperuic acid can therefore be discounted and with it the last apparent exception among diterpenoids to the rule of A/B/C trans-anti-stereochemistry.

Henrick and Jeffries isolated new diterpene acids, eperu-8(20)-ene-15, 18-dioic acid (\( \text{111} \)), 15-hydroxyeperu-8(20)-en-18-oic acid (\( \text{112} \)) and the \( \Delta^9 \)-butenolide \( \text{113} \) from Ricinocarpus muricatus.

\[
\begin{align*}
\text{111} & : & \text{COOH} \\
\text{112} & : & \text{CH}_2\text{OH} \\
\text{113} & : & \text{O}_2\text{O} \\
\end{align*}
\]

Jeffries and Payne isolated four new diterpenes and six known diterpenes from a new Beyeria species. Three of the new diterpenes were labdane derivatives \( \text{114}, \text{115}, \text{and 116} \), and another one was kaurane derivative (see Phyllocladane section). One of the known diterpenes was 13-epi-(−)-manoyl oxide (\( \text{117} \)).

\[
\begin{align*}
\text{114} & : & \text{HOCH}_2\text{OH} \\
\text{115} & : & \text{HOCH}_2\text{O} \\
\text{116} & : & \text{HOOC} \\
\text{117} & : & \text{O}_2\text{O} \\
\end{align*}
\]

The stereochemistry of marrubiin, a major crystalline constituent of Marrubium vulgare, was shown to be \( \text{118} \) by Fulke and McCrindle on the basis of N.M.R. data, provided that a residual uncertainty on the stereochemistry of C-9 remains. Breccia et al. investigated the incorporation of [1,4-\( ^\text{14} \)C]-succinic acid and [2,3-\( ^3 \)H]-succinic acid into Marrubium vulgare, and suggested that at least three carbon atoms of each succinic acid unit are involved in the marrubiin biogenesis, and the pathway of incorporation of [1,4-\( ^\text{14} \)C]-succinic acid into marrubiin via isoprenic units could involve only one \( ^\text{14} \text{COOH} \) of the acid for each isoprenic unit.

Cocker et al. isolated from ligroin extract of Copaifera officinalis a dextrorotatory hardwickic acid (\( \text{119} \)), an enantiomer of the acid isolated by Dev et al. from Hardwickia pinnata.

* See below; ref. 63.
The Chemistry on Diterpenoids in 1965

Tinophyllone, a diterpenoid from *Tinomiscium philippinense*, was shown to have structure 120 by G. Aguilar-Santos.57

The chemistry of larixol, a constituent from *Larix* resin, was investigated by three groups. Haeuser58> assigned structure 121 to larixol which was obtained from larch resin by alkaline hydrolysis of the neutral fraction extracted by petroleum ether. Norin et al.59> investigated the structures and configurations of larixol and larixyl acetate, and proposed formulas 122 and 123. Sandermann and Bruns60> studied the chemistry of larixol. They also studied on its configuration and assigned the stereochemistry 124.61

Norin et al.59> converted larixol into 13-epi-manool (125) via tosylation followed by lithium aluminum hydride reduction. On the basis of this conversion, they determined the stereochemistry of C-13. On the other hand, Sandermann and Bruns61> compared oxidation products from larixol and manool. On treatment with potassium permanganate in acetone and dehydroxylation, larixol gave a ketal 126, which was identified with the sample obtained from manool (127) by Schenk et al.62> Moreover, ketol 128 on Wolff-Kishner reduction gave tetrahydromanool (129). From these results, they concluded the stereochemistry of C-13 to be shown in 124.

The configuration of C-13 is only a different point between 122 and 124. Norin et al.59> converted larixol into 13-epi-manool (125) via tosylation followed by lithium aluminum hydride reduction. On the basis of this conversion, they determined the stereochemistry of C-13. On the other hand, Sandermann and Bruns61> compared oxidation products from larixol and manool. On treatment with potassium permanganate in acetone and dehydroxylation, larixol gave a ketal 126, which was identified with the sample obtained from manool (127) by Schenk et al.62> Moreover, ketol 128 on Wolff-Kishner reduction gave tetrahydromanool (129). From these results, they concluded the stereochemistry of C-13 to be shown in 124.
Henrick and Jefferies\textsuperscript{63} isolated three new diterpenes from *Ricinocarpus muricatus* and showed their structures to be eperuane-8\(\beta\),15-diol (130), eperuane-8\(\beta\),15,18-triol (131), and 15, 16-dihydroxyeperu-8(20)-en-18-oic acid (132). They also showed that eperuic acid* (133) and labd-8(20)-en-15-oic acid are antipodal apart from C-13.

Rowe and Shaffer\textsuperscript{65} revised structures\textsuperscript{65} postulated for diterpenes isolated from *Pinus contorta*; “hydroxyepimanool” is 13-epitorulosol (134), “contortadiol” is identical with agathadiol (135), and “contortolal” should be renamed agatholal (136).

Cava et al.\textsuperscript{66} prepared a number of new transformation products of andrographolide (137). The structure of iso-andrographolide, an acid transformation product of andrographolide, was shown to be 138. The stereochemistry of C-3 and C-9 in andrographolide was proved to be shown in 137 from chemical results. The configuration of C-4 substituents was supported by N.M.R. data.

Grant et al.\textsuperscript{67} isolated three oxido-diterpenes from *Dacrydium colensoi* and characterized them to be 2\(\alpha\)-hydroxymanoyl oxide (139), 2,3-dicarboxy-2,3-secomanoyl oxide (140), and 2-oxo-3-oxamanoyl oxide (141). Grant and Munro\textsuperscript{80} showed the structure of another oxidoditerpene isolated from the heartwood of *D. colensoi* to be 18-hydroxy-2-ketomanoyl oxide (142).

\* See above; ref. 50 and structural formula 109.
Halsall et al. showed the structure of cascarillin A, an epoxy-furanoid diterpene isolated from Cascarilla bark to be \( \text{143} \). Mousseron-Canet and Mani studied selective epoxidations of manool, manoyl acetate, and manoyl formate. Bory and Fetizon synthesized manoyl oxide (\( \text{144} \)) by Hofmann degradation of quaternary base \( \text{145} \). Sibirtseva et al. investigated the structure of the carbonyl compound formed in oxidation of sclareol (\( \text{146} \)) with chromate mixture and showed it to be \( \text{147} \). Kucherov et al. tried the acid-catalyzed cyclization of monocyclofarnesylacetone and found a new route of stereospecific cyclisation of isoprenoids.

V. PHYLLOCLADANE AND ITS RELATED SKELETONS

Jefferies and Payne isolated many kinds of diterpenes from a new Beyeria species. One of the new diterpenoids belongs to kaurane derivative. The structure was shown to be \( \text{148} \). The known substances of this group which were isolated from the same plant source were \((-\)-kaur-16-en-19-oic acid (\( \text{149} \)), 16\(\beta\)(\(-\)-kaurane-16, 17, 19-triol (\( \text{150} \)), and 16\(\alpha\)(\(-\)-kaurane-3\(\alpha\), 17, 19-triol (\( \text{151} \)). Moreover, diol \( \text{152} \) and hydroxy acid \( \text{153} \), both of which had not yet been isolated from natural source, but had been already derived from diacid \( \text{154} \), were isolated.

Henrick and Jefferies isolated the known 16, 17-dihydroxy-16\(\beta\)(\(-\)-kauran-19-oic acid (\( \text{148} \)) and a new acid, that is, 1\(\alpha\), 19-dihydroxy-16\(\alpha\)(\(-\)-kauran-17-oic acid (\( \text{155} \)) from Ricinocarpus stylosus. The latter is a first example of 1\(\alpha\)-hydroxy-\((-\)-kaurane derivative, and an interesting compound as a possible precursor of enmein (\( \text{282} \)) and grayanotoxin (\( \text{156} \)) in the biogenesis.
Quilico et al.\cite{75} investigated the structure of atracyligenin, the aglycone of atracyloside and proposed structure 157 to it.

Briggs et al.\cite{76} studied the reaction of N-bromosuccinimide on (-)-isokaurene (158), isophyllocladene (159), and 17-norphylloloclad-15-ene (160). Phyllocladene (161) on bromination with bromine in carbontetrachloride gave dibromo derivative 162, which was dehydrobrominated during the chromatography on alumina to yield 17-bromophylloclad-15-ene (163). The latter was identical with the N-bromosuccinimide bromination product of isophyllocladene (159).

Elizarava and Kuzoukov\cite{77} suggested partial structure 164 or 165 to plectrin, a diterpene.

Briggs et al.\cite{78} revised the structures 166 and 167 postulated previously for the products of the reaction between isophyllocladene (159) and diazotised 2, 4-dinitroaniline to 168 and 169, respectively.

Jiménez et al.\cite{79} studied the stereochemistry of a degradation product from tubicorytin and presented its steric structure 170; the stereochemistry of tubicorytin was
The Chemistry of Diterpenoids in 1965

Mori and Matsui\textsuperscript{80} synthesized methyl (±)-8α-carboxymethyl-podocarpan-13-one-4β-carboxylate (as 171), a degradation product of steviol (172).

Herz et al.\textsuperscript{81} synthesized dihydroisohibaic acid (173) and isohibane (174) from isopimaric acid (67).

Kitahara and Yoshikoshi\textsuperscript{82} published a detailed paper on the structure and stereochemistry elucidation of hibaene (175), a diterpene from the leaves of Thujaopsis dolabrata.

Ireland and Mander\textsuperscript{83} carried out the total synthesis of (±)-hibaene. The route is shown in Scheme 2 (Each compound represents d,l-compound.).
Eiichi FUJITA

Kapadi and Dev\(^{84}\) converted (+)-hibaene (antipode of 175) into (−)-kaurene. They carried out BF\(_3\)-catalyzed rearrangement of epoxide 176 to unsaturated alcohol 177, which was oxidised to ketone 178 and then converted to kaurene (179) by Wolff-Kishner’s reduction. Dev et al.\(^{85}\) isolated (+)-hibaene, (−)-pimaradiene, and three new diterpenes from Erythroxylon monogynum. They assigned structures 180, 181, and 182 to (−)-atisirene, (−)-isoatisirene, and (+)-devadarene, respectively.

VI. GIBBANE AND ITS RELATED SKELETONS

Borchert\(^{86}\) examined rejuvenation of apical meristens in Acasia melanoxylon by gibberellic acid. Maheshwari and Johri\(^{87}\) found gibberellin-like active substances during seed development in Zephyranthes lancasteri.

Dolby and Iwamoto\(^{88}\) examined the acid-catalyzed cyclizations of dienone 183 and allylic alcohol 184 as models for the synthesis of the C-D ring system of gibberellic acid and related compounds. Neither compound gave rise to the desired tricyclic materials in appreciable yield. The preparation of allylic alcohol 184 and dienone 183 were described.

House and Darms\(^{89}\) reported an improved synthetic route of hexahydrofluorene derivative 185. They prepared its monoethylenic ketone carboxylic acid 186 and esters 187 and 188. The sodium borohydride reduction of the latter two esters gave diols.

Stork et al.\(^{90}\) carried out a cyclization of compound 189 with potassium in a mixture of tetrahydrofuran and anhydrous ammonia containing ammonium sulfate and separated tetracyclic alcohol 190 from the reaction mixture. The alcohol was converted to ketone 191 by acid-catalyzed rearrangement.
Banerjee et al.\textsuperscript{91} published a stereoselective total synthesis of (±)-hexahydrofluorenone carboxylic acid 192 (represented as an enantiomer). The cyclization of B-ring consisted of the heating of ester 193 with polyphosphoric acid.

Loewenthal and Malhotra\textsuperscript{92} synthesized (±)-gibberic acid (as 194), a key degradation product of gibberellic acid from o-tolylacetonitrile via the route shown in Scheme 3.

Galt and Hanson\textsuperscript{93} converted fujenal (195) or 7-hydroxykaurenolide (196) to ketotricarboxylic acid mono ester 197 via several steps reactions. The anhydride of compound 197 on pyrolysis at 280° afforded gibbane derivative 198.

Fujenal (195) on lithium aluminum hydride reduction followed by chromic acid oxidation gave lactone aldehyde 199, which on base-catalyzed cyclization yielded gibbane derivative 200. 7-Epi hydroxykaurenolide (201), a sodium borohydride re-
duction product of 7-oxo-kaurenolide, on tosylation and refluxing with methanolic potassium hydroxide gave, after methylation of the crude product, a 10–15% yield of a B-noraldehyde 202 in addition to a major product 203.

Cross and Norton\(^{94}\) isolated a new metabolite gibberellin A\(_{12}\) from the culture filtrates of Gibberella fujikuroi and showed it to have structure 204.

Galt\(^{95}\) showed the structure of gibberellin A\(_{13}\), a biogenetically interesting new metabolite from Gibberella fujikuroi, to be 2\(\beta\)-hydroxy-1\(\beta\)-methylgibbane-1\(\alpha\),4\(\alpha\),10\(\beta\)-tricarboxylic acid (205).

Mulholland \textit{et al.}\(^{96}\) prepared some new derivatives and transformation products of gibberellic acid. They\(^{97}\) also reported some reactions with gibberellin A\(_4\) (206) and A\(_7\) (207).

Hanson and Mulholland\(^{98}\) described the preparation of 8-demethylene-, 2,3-dehydro-, and some other derivatives of gibberellin A\(_9\) (208). Cross \textit{et al.}\(^{99}\) converted gibberellic acid (209) into 7-deoxy compounds. The methyl ester of dihydro-gibberellin A\(_4\), (dihydro-derivative of 208) was prepared by reduction of ditosylate of gibberellin A\(_4\) methyl ester (210) with Raney nickel. A second route utilising the “double inversion” of ring D gave the methyl ester of gibberellin A\(_4\) (206).
Hanson\textsuperscript{100} gave a discussion on the N.M.R. spectra of some gibberellin derivatives in pyridine and deuterochloroform solution. Some differences were correlated with structural features.

Cross and Norton\textsuperscript{101} investigated the biosynthesis of gibberellic acid (209). They prepared [$^{14}$C]-gibberellin A\textsubscript{12} (211) and found that the incorporation of 211 into gibberellic acid was disappointingly low (0.7\%), but that of the corresponding labelled diol (212) which was prepared from 211 by lithium aluminum hydride reduction was high (7.5\%). All the radioactivity was shown to be present in the exocyclic methylene group of the gibberellic acid. [$^{14}$C]-Gibberellin A\textsubscript{13} (213) was isolated from both of the above fermentations. Gibberellin A\textsubscript{12} and the diol can therefore act as precursors of gibberellic acid, and these compounds together with gibberellin A\textsubscript{13} may be intermediates, or closely related to intermediates, in the biosynthetic transformation of (−)-kaurene into gibberellic acid.

Kucherov et al.\textsuperscript{102} investigated mass spectrometry of gibberellins and gave discussions on fragmentations.

**VII. DITERPENE ALKALOIDS**

Ottinger et al.\textsuperscript{103} determined the structure of ivorine isolated from the bark of *Erythrophleum ivorensis* as 214.

Hauth et al.\textsuperscript{104} investigated the absolute configuration of cassaine, an *Erythrophleum* alkaloid, on the basis of N.M.R. analyses. They concluded cassaine to be represented as 215.

A new alkaloid, erythrophleguine, was isolated from the bark of *Erythrophleum guineense*.\textsuperscript{105} The alkaloid proved to have structure 216. On acid hydrolysis, it gave dimethylaminoethanol and acid 217.

From Chinese drugs *Hse-Shang-Yi-Zhi-Hao* (*Aconitum bullatifolium var. homotruchum*), aconitine, hypaconitine, bullatine B and three new bases, that is, bullatine E, F, and
Hypaconitine, aconitine, mesaconitine, talatisamine, and two new bases were isolated from Chinese Drugs, Chuanwu and Fu-tsu (*Aconitum carmichaeli*). Singh and Singh isolated five diterpene alkaloids, that is, vakognavine, an ether-soluble alkaloid which appeared to be palmatisine, vakatisine, and vakatidine, from the roots of *Aconitum palmatum*.

Finnegan and Bachman synthesized (+)-12-oxo-6,9-ethano-Δ<sup>12</sup>-octalin (as 218), a potentially useful intermediate for the total synthesis of atisine.

Wiesner et al. treated isocyanate 219 with <i>p</i>-toluenesulfonic acid in refluxing benzene for 32 hours and got a keto lactam 220 in 26% yield. The lactam on two steps of reductions gave amine 221.

They also tried a photochemical approach to the C-D ring system of atisine; irradiation of a 1% solution of enone 222 in dry tetrahydrofuran in the presence of a large excess of allene at —80° for 13 hours resulted in a complete conversion to compound 223. The latter was converted to compounds 224 and 225 via several steps.

Tahara et al. carried out syntheses of optical active compounds 226 and 227 from abietic acid (4). As the total synthesis of abietic acid has been accomplished, the syntheses of 226 and 227 from abietic acid can be regarded as formal total syntheses of these compounds.
The Chemistry on Diterpenoids in 1965

They derived, as a key intermediate, keto lactone ester 228 from abietic acid. Subsequent hydrogenolysis of the compound on 30% palladium-charcoal in acetic acid containing a small amount of sulfuric acid at 35–40° gave an acid 229 and a lactone alcohol 230. Alkaline hydrolysis of the acid afforded dicarboxylic acid 231, which was dehydrated by heating with acetic anhydride to give an anhydride 232. Treatment of the latter with urea gave imide 233, which on lithium aluminum hydride reduction yielded compound 226.

Pelletier and Locke\textsuperscript{113} reported the details of the correlation of atisine (234) and veatchine (235) via the bisnor ester 236. Atisine was converted to dicarboxylic acid derivative 237 and then selective decarboxylation was achieved via Hunsdiecker reaction of 238 followed by removing the bromine in product 239 with zinc in glacial acetic acid containing a few drops of hydrochloric acid.

Another route was also successful; the key intermediate 240 derived from atisine on oxidation with Kiliani reagent gave a seco acid 241. Subsequent Baeyer-Villiger reaction and saponification gave hydroxy acid 242, the methyl ester (243) of which on chromic acid oxidation gave keto ester 244. The latter was converted to the thio-ketal and reduced with Raney nickel to give the desired bisnor ester 236. Thus, atisine has been converted to the bisnor ester 236 by two independent routes.

Conversion of veatchine to the bisnor ester 236 was successful by a sequence of re-
actions paralleling the first route described for conversion of atisine to 236; veatchine was converted to bromo derivative 246 via dicarboxylic acid 245 and then to 236. This correlation provides the first unequivocal evidence for the common stereochemistry of the atisine- and Garrya-type alkaloids.

Pelletier and Parthasarathy\textsuperscript{114} published the details of their work on atisine chemistry and gave discussions to certain interesting chemical features of the atisine molecule.

Pelletier\textsuperscript{115} published a paper which details the elucidation of the structure (247) of atidine isolated from Aconitum heterophyllum and its correlation with the Delphinium alkaloid, ajaconine; Huang-Minlon reduction of atidine (247) furnished dihydro-atisine (248). Reduction of atidine with sodium borohydride afforded a mixture, one of the components of which was identical with dihydroajaconine (249). Thus the keto function was assigned to position 7 in atidine.

Pelletier et al.\textsuperscript{116} studied the isomerization of iso-type diterpene alkaloid salts to normal-type salts. The iso-type diterpene salts (250) were smoothly isomerized to the normal-type salts (251) at reflux temperature in such polar solvents as N, N-dimethylacetamide, N, N-dimethylformamide, dimethyl sulfoxide, phenol, the cellosolves, and carbitols. The isomerization follows first-order kinetics and the rate is greater in the proton-donor type solvents than in the non-donor type. The effect of temperature on the rate of isomerization of isoatisinium chloride in several solvents was investigated. The energy of activation, enthalpy of activation, entropy of activation, and frequency factor were calculated for isomerization in various solvents.

Huneck\textsuperscript{117} investigated a photochemical cyclization of 3α-acetoxy-urs-12-enc-24-carboxylic acid azide (252) to lactam 253.

Okamoto et al.\textsuperscript{118} reported the result of the crystallographic study of lucidusculine hydriodide; the structure of lucidusculine (254), an alkaloid of the roots of Aconitum lucidusculum, was settled on firm basis as a diterpene alkaloid possessing the (−)-kaurene
carbon skeleton. The structure of songorine, an aconite alkaloid, had been determined, but for the purpose of establishment of its absolute configuration, songorine was reduced with lithium aluminum hydride to furnish a crystalline product. It was identified with luciculine (255), an alkamine of lucidusculine, hence the structure of songorine was confirmed to be 256.

Canadian school and Japanese school\(^{119}\) presented a structural formula 257 to chasmanine, an alkaloid from *Aconitum chasmanthum*.

\[
\begin{align*}
\text{OH} & \quad \text{OH} \\
\text{OCH}_3 & \quad \text{OCH}_3 \\
\text{H}_2\text{C} & \quad \text{H}_2\text{C}
\end{align*}
\]

Achmatowicz, Jr. and Marion\(^{120}\) suggested structure 258 for homochasmanine isolated from *A. chasmanthum*.

Marion *et al.*\(^{121}\) found a remarkable difference in the oxidations of two groups of diterpene alkaloids; group A (as 259), to which aconitine-like bases possessing \(\alpha\)-configurational C-6 methoxyl group belong, on oxidation with permanganate at room temperature in the neutral medium afforded dealkylated secondary bases, whereas group B (as 260), to which lycoctonine-like bases possessing \(\beta\)-configurational C-6 methoxyl group belong, on same treatment furnished the corresponding lactams. Thus, the characteristic difference can be used for assignment of the stereochemistry at C-6 of these alkaloids.

\[
\begin{align*}
\text{OCH}_3 & \quad \text{OCH}_3 \\
\text{OCH}_3 & \quad \text{OCH}_3 \\
\text{H}_2\text{C} & \quad \text{H}_2\text{C}
\end{align*}
\]

Barton and Hanson\(^{122}\) irradiated 7\(\alpha\)-alcohol 261 derived from 7-hydroxykaurenolide (196), in benzene solution in the presence of iodine and lead tetraacetate, and got an ether 262 in high yield. They also carried out photolysis of the nitrite of the 7\(\alpha\)-alcohol 263 derived from 7,18-dihydroxykaurenolide (264) and obtained a lactam 265. The reaction clearly has potential for the partial synthesis of ajaconine (266).
The mild pyrolytic loss of acetic acid from diterpene alkaloids of aconitine type 267 (bikhaconitine) and the formation of the “pyro”-compound 269 was examined and evidence that such reactive intermediates as 268 exist has now been provided by Edwards.12 This reaction is interpreted as rapid reversible formation of ionic species 268, followed by a slower attack of acetate ion on the 18-hydrogen, as shown in Scheme 4. The replacement of the acetoxy-group by a methoxy-group at 130° is similarly explained as attack of methanol on C-8 of 268, with re-establishment of the original skeleton (268→270).

The structure and relative stereochemistry of the lactone-type diterpene alkaloid heteratisine (Aconitum heterophyllum) had been established by crystallographic and chemical methods. The absolute configuration 271 had been suggested on the basis of the expected biogenetic relationship to the aconitines possessing the regular lycoctonine-type skeleton. Aneja and Pelletier124 presented further evidence and arguments which establish the absolute configuration of heteratisine as 271 from a study of the optical rotatory dispersion curve of pyroheteratisine, (and its derivatives) a product obtained from esters of heteratisine by way of a facile thermally—induced ring cleavage reaction.

Wiesner et al.125 synthesized a compound 273 from methoxy tetralone 272 via a number of steps.
VIII. THE OTHERS

Raphael et al.\textsuperscript{126} carried out a stereoselective synthesis of meso-trans-1, 3-dimethylcyclohexane-2-acetic-1,3-dicarboxylic acid \textsuperscript{274} which is a key compound for the determination of the stereochemistry of ring A through drastic oxidation of diterpenoid resin acids.

Blake and Jones\textsuperscript{127} tried an approach to elaborate decalins of type \textsuperscript{275} from 2,2,6-trimethylcyclohexanone through an acetylenic intermediate. But they got only compound \textsuperscript{276}. Arroyo and Holcomb\textsuperscript{128} published the isolation of a pure crystalline active tumour-enhancing compound from \textit{Croton} oil and presentation of partial structure \textsuperscript{277} to the substance. Lisina et al.\textsuperscript{129} isolated abietinal and two new diterpenes, together with some sesquiterpenoids, from high boiling portion of cedar resin. One of the new diterpenes, cembrol was shown to have structure \textsuperscript{278}. Another one was shown to be a diterpene diol.

Chapman et al.\textsuperscript{130} elucidated the structure of dehydrocassamic acid which was isolated from the bark of \textit{Erythrophleum guineense} as shown in formula \textsuperscript{279}. Immer et al.\textsuperscript{131} presented structure \textsuperscript{280} to ovatodiolide, a macrocyclic diterpene from \textit{Anisomeles ovata}.

Dauben et al.\textsuperscript{132} published a detailed report on the structure elucidation, by systematic degradation, of cembrene \textsuperscript{281}, a monocyclic diterpene hydrocarbon from the oleoresin of many pine trees of the subgenus \textit{Haploxylon}. The work had been...
reported as a preliminary communication.\textsuperscript{133)}

Transformation of enmein, a bitter principle of *Isodon trichocarpus*, into \((-\)-kaurane (283) was independently accomplished by two Japanese groups, and the absolute configuration of enmein (282) was confirmed by the chemical evidence; Okamoto et al.\textsuperscript{134)} derived the key intermediate 284 from enmein via hydroxylactone ester 285 and unsaturated ester 286, whereas Fujita et al.\textsuperscript{135)} derived the same key compound (284) via 15-deoxo-dehydrodihydroenmein (287) or its acetate (288). The acyloin condensation of 284 was carried out with sodium in boiling toluene by Okamoto’s group, while the same reaction was done with sodium in liquid ammonia by Fujita’s group. The main product 289 was converted to \((-\)-kaurane (283) by a common route.

\[ \text{Equations and structures} \]

Nakanishi, Uyeo et al.\textsuperscript{136)} presented a stereochemical structure 290 to taxinine \((-0\)-cinnamoyltaxicin-II triacetate). Against this, Lythgoe et al.\textsuperscript{137)} published an evidence that a complete stereochemistry of 4, 16-dihydrotaxicin-I corresponds to structure 291, thus taxicin-II should be represented as structure 292.*

\[ \text{Equations and structures} \]

*Recent X-ray analysis by Nakanishi, Uyeo et al. resulted in a complete agreement with Lythgoe’s conclusion. (Chem. Comm. 1966, 97)
The Chemistry on Diterpenoids in 1965

Uyeo et al.\textsuperscript{138} published in detail a previous data for partial elucidation of the structure of taxinine.

Nakanishi et al.\textsuperscript{139} published a full paper of stereochemistry of grayanotoxins. Grayanotoxin-I, -II, and -III, the toxic components of \textit{Leucothoe grayana} are shown as 293, 294 and 295, respectively.

Wiesner et al.\textsuperscript{140} presented a complete structure of an insecticide ryanodine, a constituent of \textit{Ryania speciosa}; ryanodine, ryanodol, anhydroryanodine, and anhydro-ryanodol can be represented as 296, 297, 298 and 299, respectively.

\[ \text{\begin{figure}[h] \centering \includegraphics[width=\textwidth]{structure1.png} \caption{Structure of diterpenes.} \end{figure}} \]

Narayanan and Venkatasubramanian\textsuperscript{141} investigated the signals of C–4 and C–10 methyls in the N.M.R. spectra of many kinds of diterpene acids and their esters.

Weiss et al.\textsuperscript{142} published a review on ORD or CD studies of a great number of non-polar homoannular cisoid dienes. Levopimaric acid (1) and palustric acid (2) were discussed in the review.

Enzell and Ryhage\textsuperscript{143} recorded the mass spectra of 45 dicyclic diterpenes (labdane group) and interpreted them. The spectra of \(\Delta^2\)-unsaturated diterpenes, \(\Delta^{8\text{C}9}\)-unsaturated compounds, compounds with a C–8 OH group, and the terpenes with C–8–C–13 ether bridge were discussed.

Clayton\textsuperscript{144} described biosynthesis of diterpenoids in a short section in his review of biosynthesis.

Finally, quassin-analogous compounds will be described. Gaudemer and Polonsky\textsuperscript{145} presented structure 300 to glaucarubinone isolated from \textit{Simaruba glauca}. Yates et al.\textsuperscript{146} discussed the absolute configuration of glaucarubin and pointed out incorrect relative configuration of the side chain. They presented a correct configuration 301 of glaucarubin.

\[ \text{\begin{figure}[h] \centering \includegraphics[width=\textwidth]{structure2.png} \caption{Structure of diterpenes.} \end{figure}} \]

de Mayo et al.\textsuperscript{147} published that chaparrin, a bitter principle of \textit{Castela nicholsonii}, on two steps degradations gave a partially aromatized product, chaparrol (392),

(267)
which was converted, by stepwise degradations, into dihydrophenanthrene derivative 303. Thus, chaparrin was shown to have structure 304.

\[
\begin{aligned}
&\text{(302)} & \text{(303)} & \text{(304)} \\
&\text{HO011OH} & \text{HO AlbI-I3C0H°} & \text{IHO} \\
\end{aligned}
\]

Subsequently, de Mayo et al.\textsuperscript{148} investigated the stereochemistry of chaparrin and related compounds. They presented the absolute configurations 305, 306, 307 and 308 to chaparrin, chaparrol, isochaparrol, and neochaparrol, respectively.

\[
\begin{aligned}
&\text{(305)} & \text{(306)} & \text{(307)} & \text{(308)} \\
&\text{O1Iy I91-I11} & \text{I(>110} & \text{011110.} & \text{OO..S.} \\
\end{aligned}
\]

Casinovi et al.\textsuperscript{149} isolated amarolide and its monoacetate, and presented structural formulas 309 and 310, respectively, on the basis of correlation with quassin (311).

\[
\begin{aligned}
&\text{(309): } R=H & \text{(311)} \\
&\text{(310): } R=\text{Ac} \\
\end{aligned}
\]

**SUPPLEMENT**

Moody\textsuperscript{150} tried a preliminary work on the synthesis of marrubiin. The wood resin of *Agathis australis* was investigated by Enzell and Thomas,\textsuperscript{151} Lin and Liu\textsuperscript{152} extracted shonanol, a new diterpene phenol, from the wood of *Libocedrus formosana*.

Ourisson et al.\textsuperscript{153} isolated novel diterpenes related to labdane, kaurane, and a new parent hydrocarbon 312, which was named trachylobane, from deseeded pods of *Trachylobium verrucosum*; trachylobanol (313), trachylobanic acid (314), kaurenoic acid (315), isokaurenoic acid (316), 3-acetoxy-trachylobanic acid (317), 3-acetoxy-kaurenoic acid (318), and zanzibaric acid. The structures of the new diterpenes were determined by spectral data and chemical degradations; a correlation between derivatives of kaurane and trachylobane was shown.\textsuperscript{154} Reactions of trachylobane
The Chemistry on Diterpenoids in 1965

derivatives were investigated. Finally, the structure of 319, a new compound extracted from T. verrucosum as acetate and named zanzibaric acid, was determined by degradation and from spectral data.

\[
\begin{align*}
(312): R&=\text{CH}_3; R'=\text{H} \\
(313): R&=\text{CH}_2\text{OH}; R'=\text{H} \\
(314): R&=\text{COOH}; R'=\text{H} \\
(315): R&=\text{H} \\
(316): R&=\text{COOH}; R'=\text{OAc} \\
(317): R&=\text{COOH}; R'=\text{OAc} \\
(318): R&=\text{OAc} \\
(319): R&=\text{CH}_2\text{OH}
\end{align*}
\]

The isolation of levopimaric acid from pine oleoresin has been described in Organic Syntheses. A report of discussion on absolute configuration at C-13 of labdanolic acid has been published. A review of recent studies on diterpene alkaloids by an Italian author has been published.

**REFERENCES**

(3) W.H. Schuller and R.V. Lawrence, ibid., 30, 2080 (1965).
(8) B.A. Parkin, Jr. and G.W. Hedrick, ibid., 30, 2356 (1965).
(9) E. Wenkert and B.L. Mylar, ibid., 30, 4387 (1965).
(22) H. Grylach, Pharmazie, 20, 523 (1965).
(45) G. Weissmann and K. Bruns, Naturwissenschaften, 52, 185 (1965).
(57) G. Aguilar-Santos, Chem. and Ind. (London), 1965, 1074.
(60) W. Sandermann and K. Bruns, Naturwissenschaften, 52, 560 (1965).
(68) P.K. Grant and M.H.G. Munro, Tetrahedron, 21, 3599 (1965).
(71) S. Bory and M. Fetizon, ibid., 1965, 148.
The Chemistry on Diterpenoids in 1965

(84) A.H. Kapadi and S. Dev, ibid., 1965, 1255.
(86) R. Borchert, Naturwissenschaften, 52, 65 (1965).
(87) S.C. Maheshwari and M.M. Johri, ibid., 52, 66 (1965).
(93) R.H.B. Galt and J.R. Hanson, ibid., 1965, 1565.
(95) R.H.B. Galt, ibid., 1965, 3143.
(97) D.C. Aldridge, J.R. Hanson, and T.P.C. Mulholland, ibid., 1965, 3539.
(98) J.R. Hanson and T.P.C. Mulholland, ibid., 1965, 3550.
(99) B.E. Cross, J.R. Hanson, and R.N. Speake, ibid., 1965, 3555.
(100) J.R. Hanson, ibid., 1965, 5036.
(113) S.W. Pelletier and D.M. Locke, ibid., 87, 761 (1965).
(114) S.W. Pelletier and P.C. Parthasarathy, ibid., 87, 777 (1965).
(115) S.W. Pelletier, ibid., 87, 799 (1965).
Eiichi Fujita

(154) *idem.*, *ibid.*, 1965, 2888.

(272)