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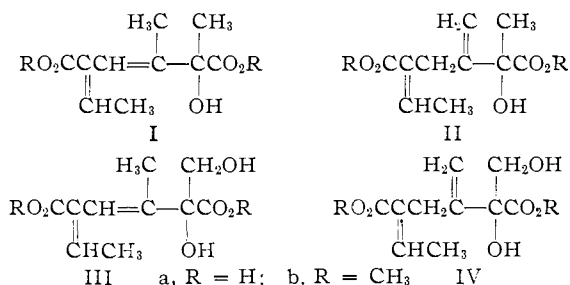
## The Structure of Riddelic Acid and the Stereochemistry of Necic Acids

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A further study of the structure of riddelic acid has led to rejection of the previously proposed formula IIIa in favor of formula IVa. The evidence for formula IVa is based on the ultraviolet and n.m.r. spectra of dimethyl riddellate and the dimethyl ester of  $\alpha$ -methylene- $\alpha'$ -ethylideneglutaric acid, the lead tetraacetate oxidation product of riddelic acid. Chemical confirmation for the terminal methylene group is provided by oxidation of  $\alpha$ -methylene- $\alpha'$ -ethylideneglutaric acid with osmium tetroxide and sodium metaperiodate and isolation of formaldehyde as its dimedone derivative. The comparison of the n.m.r. spectra of a variety of analogous natural acids and esters with trisubstituted  $\alpha,\beta$ -olefinic acids and esters revealed that from the position of the olefinic proton peak, the *cis* or *trans* configuration of the trisubstituted olefinic acid can be established.

The structure of riddelic acid, the alkaline hydrolysis product of the alkaloid riddelline, was the subject of a previous paper from this Laboratory.<sup>1</sup> Convincing evidence was presented for the presence of two double bonds, an  $\alpha$ -hydroxy acid and a glycol system in riddelic acid. The close similarity of the infrared and ultraviolet spectra of riddelic acid, seneciophyllic acid and of their retronecine and dimethyl esters indicated that the double bonds in these two acids are similarly situated. The structure of seneciophyllic acid previously had been proposed<sup>2</sup> as I; the alternate structure II for seneciophyllic acid was considered at that time but structure I was preferred since no formaldehyde was obtained on ozonolysis, Kuhn-Roth determination gave a value 2.2 for C-methyl groups, and the infrared spectrum failed to show the characteristic absorption for a terminal methylene group. By analogy, then, riddelic acid was represented as III



Results have been reported recently by Masamune<sup>3</sup> on a study of isoseneciophyllic acid<sup>4</sup> indicating that structure II is preferable to structure I. This has led the authors to a reinvestigation of the structure of riddelic acid.

The late E. A. Braude commented that the ultraviolet spectral band (215  $m\mu$ ) was abnormal for the conjugated olefinic double bonds postulated in seneciophyllic acid and proposed (unpublished

communication) that the  $\text{---CH=C---}$  function in formula I was probably  $\text{---CH---CH---}$ . This latter

(1) R. Adams and B. L. Van Duijren, *THIS JOURNAL*, **75**, 4638 (1953).

(2) R. Adams, T. R. Govindachari, J. H. Looker and J. D. Edwards, Jr., *ibid.*, **74**, 700 (1952).

(3) S. Masamune, *Chemistry & Industry*, 21 (1959).

(4) There has been some confusion in the use of the names isoseneciophyllic and seneciophyllic. The term isoseneciophyllic acid as used by Masamune represents the compound formed by hydrolysis of seneciophylline and called by other investigators seneciophyllic acid.

structure is very unlikely, for upon lead tetraacetate oxidation of seneciophyllic acid the hydroxy acid is converted to an optically inactive ketone. The ketone, if it contained a cyclopropane ring, would almost certainly be optically active.

Masamune<sup>3</sup> was also dubious about structure I for seneciophyllic acid because of the ultraviolet

spectrum and suggested that the  $\text{---CH=C---}$  function might better be represented by  $\text{---CH}_2\text{---C---}$ .

The chemical evidence for this alternative structure was not too convincing. The ultraviolet spectra of the assumed but uncharacterized oily triol and oily methyl ketone are of questionable diagnostic value since, in preparing these products, the reduction of the  $\alpha,\beta$ -unsaturated ester to a saturated alcohol during the lithium aluminum hydride treatment of methyl seneciophyllate was a distinct possibility. Of a more positive character was the isolation of 0.32 mole of formaldehyde by the oxidation of seneciophyllic acid when a mixture of potassium permanganate and sodium periodate was used as oxidizing agent. However, no band for a terminal methylene group could be found in the infrared spectrum. His more convincing evidence for structure II was the n.m.r. spectral data.

Chemical evidence previously presented favored formula III for riddelic acid. This conclusion was reconciled with the ultraviolet data,<sup>3,5</sup> which do not indicate a normal conjugated olefinic double bond system, in two ways. A cross-conjugated system might result in a different absorption band. Cross-conjugated systems of this type have not been studied spectrally and indeed only very few prototypes are known. Significant also is the fact that a model of structure III indicates that the two olefinic double bonds will not be coplanar unless a strain is applied; structure IV may be built with less strain than structure III. The only convincing conclusion from earlier work was, therefore, that no 1,3-diene system in complete conjugation with a carboxyl group was present in riddelic acid.

The n.m.r. spectrum of dimethyl riddellate<sup>6</sup> was determined in  $\text{CDCl}_3$  at different concentra-

(5) C. C. J. Culvenor and T. A. Geissman, *Chemistry & Industry*, 366 (1959).

(6) R. Adams, K. E. Hamlin, C. F. Jelinek and R. F. Phillips, *THIS JOURNAL*, **64**, 2760 (1942).

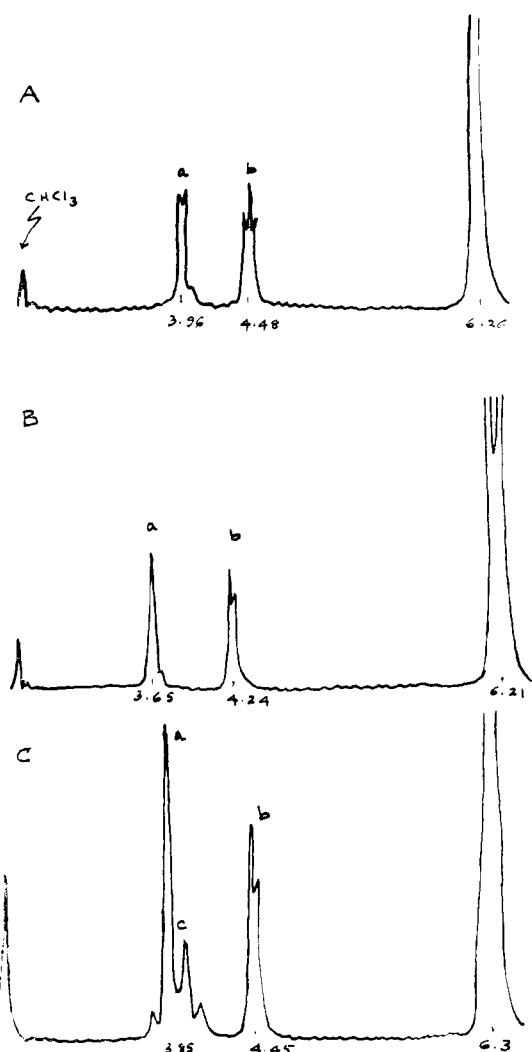
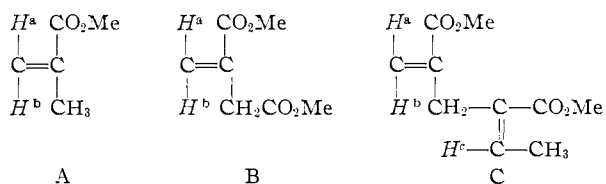


Fig. 1.—A, methyl methacrylate (sweep rate 420); B, dimethyl itaconate (sweep rate 480); C, dimethyl  $\alpha$ -methylene- $\alpha'$ -ethylidene-glutarate (sweep rate 420). Lettered peaks on the spectra correspond to identically labeled protons in the structural formula.



tions. The shape and position of the hydroxyl proton signals were found to vary depending on the concentration. Of particular significance was the presence of two peaks each of one proton area (Fig. 2B) in the vinyl region of the spectrum corresponding to the two protons of the terminal methylene group. This assignment was established more positively by observation of the n.m.r. spectra of other esters (Fig. 2) with and without terminal methylene groups. Dimethyl senecate (V) and dimethyl integerrinecate (V), a pair of *cis-trans* isomers, do not possess a terminal methylene function and their n.m.r. spectra exhibited no peaks in the region assigned for the terminal pro-

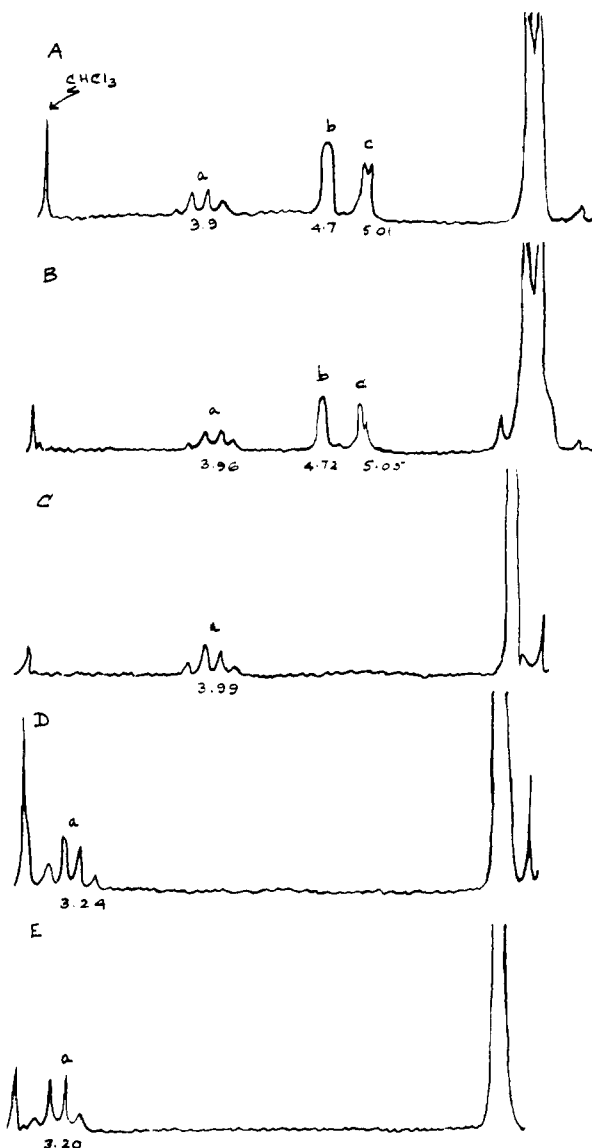
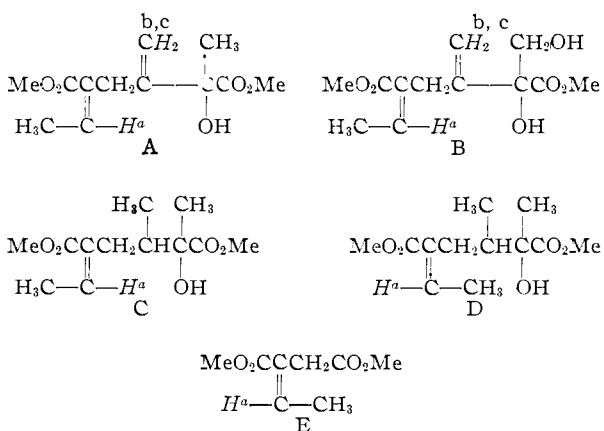
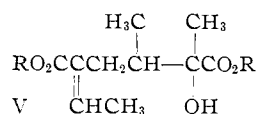


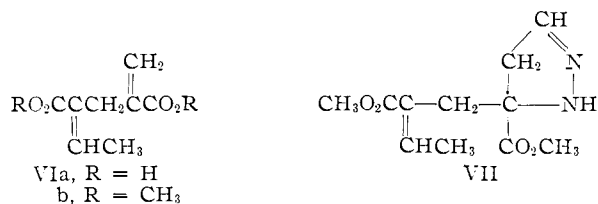
Fig. 2.—A, dimethyl seneciphyllate; B, dimethyl riddellate; C, dimethyl senecate; D, dimethyl integerrinecate; E, dimethyl ethylenesuccinate. Sweep rates 480 in all cases. Lettered peaks on the spectra correspond to identically labeled protons in the structural formula.





tons in riddelic acid. On the other hand, the spectrum of dimethyl seneciophyllate (IIb) (Fig. 2A) was very similar to that of dimethyl riddellate in the vinyl region and the peaks found agreed with those reported by Masamune.<sup>3</sup> The chemical shifts observed between the two terminal methylene protons in dimethyl seneciophyllate and dimethyl riddellate are analogous to those observed in several reported cases,<sup>3,7-9</sup> and represent the differential shielding of protons by the  $\beta$ -substituents. The spectrum of dimethyl riddellate showed the presence of a methyl group (a doublet) providing further evidence in favor of structure IV, since peaks corresponding to two methyl groups would be expected if structure III were correct.

A more reproducible spectrum (independent of concentration) could be expected of a hydroxyl-free product such as can be prepared from riddelic acid by oxidation with lead tetraacetate. The resulting optically inactive dibasic acid (VIa) was converted to its dimethyl ester VIb by reaction with a calculated amount of diazomethane at 0–10°. At room temperature and in the presence of an excess of diazomethane a pyrazoline, presumably of structure VII, resulted. The formation of the pyrazoline on the terminal methylene double bond rather than on the ethylidene double bond is preferred since the n.m.r. spectrum still retains the characteristic  $-\text{CHCH}_3$  signal (quartet 3.9). The ultraviolet spectrum of VIa is similar



to that of riddelic acid thus suggesting no rearrangement of double bonds under the extremely mild conditions of oxidation. The n.m.r. spectra of VIa and VIb provided conclusive evidence concerning their structures and thus for the structure of riddelic acid.

The spectra of VIa and VIb (Fig. 1C) are identical except for the peaks due to the methyl groups of the ester in VIb. They showed the following features: VIa: One quartet of the 1 proton area overlapped by a singlet of the 1 proton area, values

3.85, 3.95 due to one proton of the  $=\text{C}\begin{array}{l} \text{H} \\ \text{H} \end{array}$  and the single proton of the ethylidene group (quartet). 1 singlet at 4.45 of the 1 proton area due to the second proton of the  $=\text{C}\begin{array}{l} \text{H} \\ \text{H} \end{array}$ ; 1 singlet at 6.68

of the 2 proton area due to the  $-\text{CH}_2-$ ; 1 doublet at 7.9 of the 3 proton area due to the  $-\text{CH}_3$  of the ethylidene group.

VIb: in addition to all of the above peaks, VIb had two peaks (slightly split) of equal intensity, each of the 3 proton area due to the  $-\text{CH}_3$  of the  $-\text{CO}_2\text{CH}_3$  at 6.3. The two protons of the terminal methylene group thus exhibit a chemical shift of approximately 0.6 p.p.m. in each case.

The  $\tau$ -values for the terminal methylene protons in several of the simpler acids or esters are given in Table I.

TABLE I  
 $\tau$ -VALUES OF TERMINAL METHYLENE PROTONS IN DISUBSTITUTED OLEFINIC ACIDS AND ESTERS

R	$\alpha\text{HCH}\beta$		RCCO <sub>2</sub> R'		
	R'	$\alpha\text{-H}$	$\beta\text{-H}$	$\delta\alpha\beta$	
CH <sub>3</sub>	CH <sub>3</sub>	4.48	3.96	0.52	
MeO <sub>2</sub> CCH <sub>2</sub>	CH <sub>3</sub>	4.24	3.65	.59	
HO <sub>2</sub> CCCH <sub>2</sub>	H	4.26	3.70	.56	
$\begin{array}{c}    \\ \text{CHCH}_3 \\ \text{MeO}_2\text{C}\text{CCH}_2 \\    \\ \text{CHCH}_3 \end{array}$	CH <sub>3</sub>	4.45	3.85	.60	

In contrast, the chemical shifts of the two protons of the terminal methylene group in dimethyl riddellate and dimethyl seneciophyllate are 0.33 and 0.31 p.p.m., respectively. This is understandable since in the acid and ester of formula VI, a carboxyl or carbomethoxyl group is present on the adjacent carbon atom and in the former cases this group is further removed. It has been suggested that the deshielding effect<sup>10</sup> of the carbonyl group on  $\beta$ -protons is due to its anisotropy or weak hydrogen bonding. An inspection of the model of the lead tetraacetate oxidation product of riddelic acid indicates that the carbonyl group and one of the  $\beta$ -protons of the terminal methylene group are oriented in a planar *cis* conformation, a situation which would be expected to cause maximum deshielding of a  $\beta$ -proton.

TABLE II  
 $\tau$ -VALUES OF TERMINAL METHYLENE PROTONS IN DIMETHYL RIDE L LATE AND DIMETHYL SENECIOPHYLLATE

	$\alpha\text{-H}$	$\beta\text{-H}$	$\delta\alpha\beta$
Dimethyl Riddellate (IVb)	5.05	4.72	0.33
Dimethyl Seneciophyllate (IIb)	5.01	4.70	0.31

The n.m.r. spectra of methyl methacrylate (Fig. 1A) and dimethyl itaconate (Fig. 1B) have been examined and chemical shifts of the same order of magnitude between the terminal methylene protons have been observed as in the riddelic acid oxidation product VI (Table I). The lower value is assigned to the proton *cis* to the carbonyl function.

For chemical verification of structure IV oxidation of the terminal methylene function was attempted in order to isolate formaldehyde. Since ozonolysis failed with seneciophyllic acid, it was not repeated with riddelic acid. Other reagents for oxidation of terminal methylene groups such

(7) E. J. Corey, *THIS JOURNAL*, **80**, 1204 (1958).

(8) Sikh Dev, *Tetrahedron*, **9**, 1 (1960).

(9) L. M. Jackman in "Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry," Pergamon Press, New York, N. Y., 1959, p. 106.

(10) For a discussion see ref. 9, pp. 120-125.

as osmium tetroxide<sup>11</sup> or potassium permanganate<sup>12</sup> in conjunction with sodium metaperiodate are not satisfactory since a glycol system is already present in riddelic acid. To circumvent this difficulty, the glycol system was removed by oxidation with lead tetraacetate and the resulting acid VIa was then oxidized with the two reagents just mentioned. With sodium metaperiodate and potassium permanganate the yield of formaldehyde was only 21.5%, but with sodium metaperiodate and osmium tetroxide the yield of formaldehyde was 53%. Under similar conditions itaconic acid gave 52 and 67% of formaldehyde, respectively.

**Stereochemistry of Necic Acids.**—Structurally the C<sub>10</sub>-necic acids<sup>13</sup> differ from each other in the degree of unsaturation. Configurational assignments about the  $\alpha,\beta$ -olefinic bond have been made tentatively, based on ultraviolet spectral studies and melting points. Considering merely the 5,6-double bond, a *cis* arrangement of methyl and carboxyl has been assigned to senecic, seneciphyllic, riddelic and isatinecic acids, a *trans* arrangement of the same substituents to retronecic and integerrinecic acids. The establishment of structure IV for riddelic acid and a similar structure for seneciphyllic acid<sup>3</sup> has reduced the major unknown stereochemical factors in the C<sub>10</sub>-necic acids to that of *cis-trans* isomerism of the 5,6-double bond.

The usefulness of n.m.r. spectroscopy in establishing the stereochemistry of olefins and olefinic acids has been discussed recently by several authors.<sup>14-17</sup> Based on the differential shielding of the methyl protons by a carbomethoxyl group on the  $\beta$ -carbon, Jackman and co-workers<sup>16</sup> elucidated the stereochemistry of phytol and related compounds.

The n.m.r. spectra of a number of trisubstituted  $\alpha,\beta$ -olefinic acids and their esters have been determined and from the position of the single olefinic proton peak, significant data pertaining to the geometry of these compounds have been collected.<sup>18</sup> The results are listed in Table III.

Examination of the table reveals that the shielding value of the single proton in the *trans* isomer is always lower than that of the corresponding *cis* isomer. Changing the substituent X from -CH<sub>3</sub> to -C<sub>2</sub>H<sub>5</sub> to -CH(CH<sub>3</sub>)<sub>2</sub> produces little shift in the  $\tau$ -value of the olefinic proton. The remarkable agreement in the  $\tau$ -value of the olefinic proton in methyl tiglate, methyl isopropylcrotonate, dimethyl ethylidenesuccinate and dimethyl integerrinecate indicates that in all these compounds the single proton is *cis* to the carbomethoxyl group.

(11) R. Pappo, D. S. Allen, R. U. Lemieux and W. S. Johnson, *J. Org. Chem.*, **21**, 478 (1956).

(12) R. U. Lemieux and E. Von Rudolff, *Can. J. Chem.*, **33**, 1710 (1955).

(13) N. J. Leonard in "The Alkaloids," edited by R. H. F. Manske, Vol. VI, Academic Press, Inc., New York, N. Y., 1960.

(14) L. M. Jackman and R. H. Wiley, *Proc. Chem. Soc.*, 196 (1958); *J. Chem. Soc.*, 2886 (1960).

(15) R. R. Fraser, *Can. J. Chem.*, **38**, 549 (1960).

(16) J. W. K. Burrell, L. M. Jackman and B. C. L. Weedon, *Proc. Chem. Soc.*, 263 (1959).

(17) S. Fujiwara, H. Shimizu, Y. Arata and S. Akahori, *Bull. Chem. Soc. Japan*, **33**, 428 (1960).

(18) A Communication was published summarizing this information [THIS JOURNAL, **82**, 3786 (1960)].

TABLE III

$\tau$ -VALUES OF OLEFINIC PROTONS IN *trans* AND *cis* (WITH RESPECT TO CH<sub>3</sub> AND CO<sub>2</sub>H) TRISUBSTITUTED  $\alpha,\beta$ -OLEFINIC ACIDS AND ESTERS<sup>a</sup>

CH <sub>3</sub> CH    XCCO <sub>2</sub> R X	<i>trans</i>		CH <sub>3</sub> CH    RO <sub>2</sub> CCX R		<i>cis</i> X	$\tau$
	H	$\tau$	H	$\tau$		
CH <sub>3</sub>	H	3.03	H	CH <sub>3</sub>	3.82	
CH <sub>3</sub>	CH <sub>3</sub>	3.28	Me	CH <sub>3</sub>	4.03	
C <sub>2</sub> H <sub>5</sub>	H <sup>b</sup>	3.00	H	C <sub>2</sub> H <sub>5</sub> <sup>c</sup>	3.82	
(CH <sub>3</sub> ) <sub>2</sub> CH	CH <sub>3</sub> <sup>c</sup>	3.30	H	CH <sub>2</sub> CCO <sub>2</sub> H <sup>d</sup>	3.70	
MeO <sub>2</sub> CCH <sub>2</sub>	CH <sub>3</sub> <sup>e</sup>	3.20	Me	CH <sub>2</sub> CCO <sub>2</sub> Me    CH <sub>2</sub>	3.95	
Dimethyl integerrinecate		3.24	Dimethyl senecate		3.99	
			Dimethyl riddellate		3.96	
			Dimethyl seneciphyllate		3.90	
			Dimethyl isatinecate		3.89	

<sup>a</sup> All compounds studied except  $\alpha$ -ethylisocrotonic acid were isomerically pure. The sample of  $\alpha$ -ethylisocrotonic acid available was a mixture of *cis* and *trans* compounds and consequently had quartets at 3.82 and 3.00 corresponding to *trans* and *cis* protons, respectively. <sup>b</sup> E. Blaise and P. Bagard, *Ann. chim.*, **11**, 111 (1907). <sup>c</sup> R. Adams and B. L. Van Duuren, *THIS JOURNAL*, **74**, 5349 (1952). <sup>d</sup> Ref. 1. <sup>e</sup> Ref. 19.

Similarly, the values of the single proton in methyl angelate, dimethyl  $\alpha$ -methylene- $\alpha'$ -ethylidene-glutarate, dimethyl seneciphyllate, dimethyl isatinecate and dimethyl senecate point to identical stereochemistry in these compounds.

The sensitivity of this correlation of *cis* and *trans* isomers is apparent by comparing the difference of the  $\tau$ -values of the ethylidene protons in the *cis-trans* pair dimethyl senecate and dimethyl integerrinecate (0.77) with the differences of the values of the pairs methyl angelate and methyl tiglate (0.75),  $\alpha$ -ethylcrotonic acid and  $\alpha$ -ethylisocrotonic acid (0.82). Thus the orientation of groups about the olefin linkage in the necic acids, assigned on the basis of ultraviolet spectra and melting points, is confirmed. Although the n.m.r. spectrum of retronecic acid has not been determined, the *trans* conformation previously assigned is confirmed on the basis of its geometric relationship to isatinecic acid.

The shielding values of the methyl protons<sup>15</sup> also provide a means of determining the stereochemistry of the double bond, but the single proton values are to be preferred due to their greater sensitivity to environmental changes. The values of methyl peaks are shown in Table IV.

Comparison of Tables III and IV shows that between the *cis* and *trans* compounds the shift in the methyl proton values is about 0.2 p.p.m. whereas the shift in the olefinic proton values is 0.8 p.p.m.

An additional use of the olefinic proton peaks is in analysis of a mixture of *cis* and *trans* isomers. Since the peaks are well separated, difficulties due to overlapping are not encountered. The n.m.r. spectrum of a mixture of dimethyl senecate and dimethyl integerrinecate exhibited two quartets at 3.1 and 3.96 p.p.m. corresponding to the *cis*

TABLE IV

$\tau$ -VALUES OF METHYL PROTONS IN TRISUBSTITUTED OLEFINIC ACIDS AND ESTERS

		HCCH <sub>3</sub> <i>trans</i> RO <sub>2</sub> C=CCX		HCCH <sub>3</sub> <i>cis</i> XCCO <sub>2</sub> R	
Tiglic acid	8.14		Angelica acid		7.94
Methyl tiglate	8.25		Methyl angelate		8.05
Dimethyl integerrinecinate	8.14		Dimethyl senecinate		7.94
Dimethyl ethylidene-succinate	8.16		Dimethyl seneciophyllate		7.92
Methyl isopropylcrotonate	8.16		Dimethyl riddellate		7.94
$\alpha$ -Ethylcrotonic acid <sup>a</sup>	8.11		Dimethyl $\alpha$ -methylene- $\alpha'$ -ethylidene-glutarate		7.93

<sup>a</sup> Precise measurement of " $\tau$ " values for the methyl protons of  $\alpha$ -ethylisocrotonic acid was not possible due to overlapping of peaks; see text and footnote a, Table III.

and *trans* olefinic protons. The relative areas under the peaks were proportional to the ratio of the components. In contrast, the methyl proton peaks in a mixture of *cis* and *trans* compounds are of little value in estimating the ratios of components present in the mixture. In the methyl region of the spectrum the doublets overlapped one another and hence accurate measurement of  $\tau$ -values was not possible.

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### Experimental

All n.m.r. spectra reported in this paper were determined on a Varian high resolution spectrometer at 60 Mc./second. Spectra were obtained in CDCl<sub>3</sub> using tetramethylsilane as an internal standard. The peaks due to the ethylidene proton appeared in all cases as quartets and the values are reported for the center of each quartet. Values are expressed in parts per million on the " $\tau$ -scale" as defined by Tiers (*J. Phys. Chem.*, **62**, 1151 (1958)). We are thankful to Mr. Van Auken for providing the spectra of tiglic and angelic acids and their esters.

Infrared spectra were obtained with a Perkin-Elmer double beam spectrometer. Ultraviolet spectra were obtained in absolute methanol, unless otherwise stated, with a Cary automatic recording spectrophotometer.

**Riddelic Acid.**—Riddelline was hydrolyzed with aqueous barium hydroxide as described earlier.<sup>1,6</sup> The anhydrous acid was crystallized from dry ether-benzene in the ice-box; prisms, m.p. 102° (lit.<sup>6</sup> m.p. 102–103°); ultraviolet spectrum  $\lambda_{\max}$  215 m $\mu$ ,  $\epsilon_{\max}$  8650.

**Dimethyl Riddellate.**—To a solution of 200 mg. of riddelic acid in 15 ml. of ether was added with stirring a calculated amount of an ethereal solution of diazomethane (estimated by adding an aliquot to an excess of benzoic acid in ether and titrating the excess of benzoic acid against standard sodium hydroxide solution). The solvent was removed and the residual oil distilled in vacuum; an almost colorless oil distilled over at 124–126° (0.2 mm.) (air-bath),  $n_D^{25}$  1.4860,

(lit.<sup>6</sup> b.p. 144–145° (1 mm.),  $n_D^{20}$  1.4870, yield 190 mg.; ultraviolet spectrum  $\lambda_{\max}$  215 m $\mu$ ,  $\epsilon_{\max}$  8050).

*Anal.* Calcd. for C<sub>12</sub>H<sub>18</sub>O<sub>6</sub>: C, 55.8; H, 7.25. Found: C, 55.75; H, 7.20.

**Oxidation of Riddelic Acid with Lead Tetraacetate:  $\alpha$ -Methylene- $\alpha'$ -ethylidene-glutaric Acid.**—Riddelic acid was oxidized as described previously<sup>1</sup>; m.p. 112–113° (lit.<sup>1</sup> m.p. 114°), yield 70%; ultraviolet spectrum  $\lambda_{\max}$  210 m $\mu$ ,  $\epsilon_{\max}$  8250.

**Dimethyl  $\alpha$ -Methylene- $\alpha'$ -ethylidene-glutarate.**—A calculated amount (2 moles per mole of acid) of an ethereal solution of diazomethane was added to a solution of 250 mg. of  $\alpha$ -methylene- $\alpha'$ -ethylidene-glutaric acid in 5 ml. of chloroform kept below 10° in an ice-bath. When the reaction was complete, the solution was evaporated to remove the solvents. Distillation at 100–102° (0.5 mm.) (air-bath) gave a colorless oil.

*Anal.* Calcd. for C<sub>10</sub>H<sub>14</sub>O<sub>4</sub>: C, 60.59; H, 7.12. Found: C, 60.51; H, 7.02.

**Dimethyl  $\alpha$ -Pyrazolono- $\alpha'$ -ethylidene-glutarate.**—To a solution of 300 mg. of  $\alpha$ -methylene- $\alpha'$ -ethylidene-glutaric acid in 10 ml. of ether was added an excess of an ethereal solution of diazomethane. The mixture was left at room temperature for 2 hr. and the ether removed under reduced pressure. The residual oil was distilled in vacuum to give a pale yellow oil, b.p. 103–104° (0.1 mm.) (air-bath); ultraviolet spectrum  $\lambda_{\max}$  215 m $\mu$ ,  $\epsilon_{\max}$  5875.

*Anal.* Calcd. for C<sub>11</sub>H<sub>16</sub>N<sub>2</sub>O<sub>4</sub>: C, 54.98; H, 6.66; N, 11.66. Found: C, 55.02; H, 6.91; N, 9.99.

**Dimethyl Ethylidenesuccinate.**—A mixture of 10 g. of dimethyl fumarate, 15.6 g. of nitroethane and 5.6 g. of diethyl mine was kept at room temperature for 6 days during which time the color turned red. The first fraction removed was nitrosodiethylamine; further distillation gave a colorless oil, b.p. 56–57° (0.2 mm.),  $n_D^{25}$  1.4542 (lit.<sup>19</sup> b.p. 73–74° (1.5 mm.),  $n_D^{20}$  1.4553).

**Integerrinecic acid** was prepared from senecic acid lactone<sup>20</sup> as previously described.<sup>21</sup>

**Oxidation of  $\alpha$ -Methylene- $\alpha'$ -ethylidene-glutaric Acid with Potassium Permanganate-Sodium Metaperiodate.**—A solution of 120 mg. of  $\alpha$ -methylene- $\alpha'$ -ethylidene-glutaric acid in 10 ml. of water was mixed with a solution of 400 mg. of sodium metaperiodate in 10 ml. of water and 1 ml. of a solution of 400 mg. of potassium permanganate in 50 ml. of water. The pH of the mixture was adjusted to 7.5–8.0 by the addition of 0.1 N potassium carbonate solution. The mixture was left at room temperature for 18 hr. At the end of this period, the reaction mixture was acidified by the addition of 30 ml. of 0.2 N sulfuric acid. The clear solution was steam distilled and the distillate collected in a saturated solution of dimedone. A precipitate of formaldehyde-dimedone derivative appeared which was collected, dried and weighed. Recrystallized from dilute ethanol it gave 49 mg. (21.5%) of fine needles, m.p. 186–187°.

**Osmium Tetroxide-Sodium Metaperiodate.**—To a stirred solution of 100 mg. of  $\alpha$ -methylene- $\alpha'$ -ethylidene-glutaric acid in 10 ml. of water was added 50 mg. of osmium tetroxide, then in small portions, 500 mg. of powdered sodium metaperiodate. The color gradually faded and a clear yellow solution was obtained. The stirring was continued for an additional 2.5 hr. The solution was steam distilled and to the steam distillate was added a saturated solution of dimedone. On shaking and after standing for 30 min., a white precipitate separated. It was filtered, dissolved in 10 ml. of dilute ethanol and a few drops of concentrated hydrochloric acid added. After boiling for 5 min., the solution was filtered. On cooling, the filtrate yielded 86 mg. (53%) of formaldehyde-dimedone derivative.

**Oxidation of Itaconic Acid.**—Itaconic acid was oxidized by methods 1 and 2 described above. Yields of 52 and 67% of formaldehyde were obtained, respectively, in the two cases.

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(21) M. Kropman and F. L. Warren, *J. Chem. Soc.*, 700 (1950).