0.5 hr. The cooled sulfuric acid solution was poured into ether, and the ether was decanted. The residue was dissolved in water and 35% perchloric acid added. The perchlorate salt was collected and recrystallized from methanol–ethyl acetate affording 2.8 g (89%) of yellow needles, mp 209–211°.

Anal. Calcd for $C_{13}H_8Cl_3NO_4$: C, 44.79; H, 2.31; N, 4.02. Found: C, 44.82; H, 2.28; N, 4.31.

1-(2′,5′-Dichlorobenzyl)-2-(1,3-dioxolan-2-yl)pyridinium Bromide (XIIc).—The crude 2,5-dichlorobenzyl bromide (obtained by bromination of 5 g of 2,5-dichlorotoluene in carbon tetrachloride solution, under irradiation from a sunlamp and isolated simply by evaporation of the solvent) was allowed to react with 3 g of 2-(1,3-dioxolan-2-yl)pyridine in 3 ml of tetramethylenesulfone as described in the preparation of XIIb. The product crystallized from methanol–ethyl acetate as colorless plates, mp 144–146°.

Anal. Calcd for $C_{15}H_{14}BrCl_2NO_2$: C, 46.06; H, 3.61; N, 3.58. Found: C, 46.13; H, 3.68; N, 3.54.

7,10-Dichloroacridizinium (XIX) Perchlorate *via* Cyclization.—The quaternary salt XIIc was cyclized in sulfuric acid as described for the preparation of 8,10-dichloroacridizinium (XVIII) perchlorate. The product, obtained in 76% yield, consisted of yellow plates, mp 226–228°. The infrared spectrum and melting point were identical with those observed for the dichlorination product of the acridizinium cation and no depression of mixture melting point was observed.

Registry No.—I, 7547-88-8; III, 7777-88-0; III perchlorate, 7777-89-1; II, 7777-90-4; IV bromide, 7777-91-5; 11-methylacridizinium perchlorate, 7777-92-6; VIII, 7777-93-7; VIII picrate, 7777-94-8; X, 10026-46-7; VI bromide, 7777-95-9; IX methoperchlorate, 10026-47-8; XIII bromide, 7777-96-0; XIII perchlorate, 10043-44-4; XV, 7777-97-1; XVII, 10026-49-0; acridizinium chloride, 7777-98-2; XIX perchlorate, 10026-50-3; XIX bromide, 7777-99-3; XX, 7778-00-9; 3,5-dichlorobenzyl bromide, 7778-01-0; XIIb, 7778-02-1; XVIII perchlorate, 10026-51-4; XIIc, 10026-52-5.

Optical Rotatory Dispersion and Absolute Configuration of Some Long-Chain Hydroxy Acids[1]

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Several long-chain, unsaturated, hydroxy acids from plant sources and selected derivatives have been examined spectropolarimetrically. These measurements coupled with earlier unequivocal syntheses allow configurational assignments to be made for the saturated and, hence, the parent unsaturated hydroxy acids. Evidence is presented that the low-intensity ester transition has no effect on the observed optical rotatory dispersion (ORD) of the hydroxy acid esters. Studies with derivatives allow some suggestions to be made concerning interaction of other functional groups with the asymmetric chromophore. Where they could be rationally applied, values calculated from Brewster's rules were in good agreement with observed results in all but one case.

Several long-chain hydroxy acids which contain asymmetric centers have been isolated from natural sources.[2] The structures and, in some cases, the absolute configurations of these compounds have been determined. Serck-Hanssen[3] synthesized (+)-12-L-hydroxyoctadecanoic (hydroxystearic) acid and showed that this isomer was enantiomeric with the hydroxystearic acid derivable from castor oil thus assigning the D configuration to (−)-12-hydroxyoctadecanoic acid and to (+)-12-hydroxy-*cis*-9-octadecenoic acid (ricinoleic acid). Baker and Gunstone[4] synthesized 9-D-hydroxyoctadecanoic acid using Serck-Hanssen's method,[3] but were unable to detect measurable optical activity in their synthetic sample or in 9-hydroxyoctadecanoic acid prepared by the hydrogenation of (+)-9-hydroxy-*cis*-12-octadecenoic acid from *Strophanthus* seed oil. They suggested, however, that these acids have the same configuration by consideration of mixture melting point data. Recently Schroepfer and Bloch[5] reexamined the synthetic sample of 9-D-hydroxyoctadecanoic acid of Baker and Gunstone and found, by means of ORD measurements, that it is identical in configuration with the naturally occurring acid, thus confirming the earlier[4] suggestion.

Availability of improved instrumentation coupled with our interest in the optically active hydroxy acids of the *Dimorphothecae*[6a] and *Lesquerellae*[6b,c] led us to an ORD study of these acids and some of their derivatives. From the results with the saturated derivatives we established the absolute configurations of the dimorphecolic[6a] [(+)-9-hydroxy-*trans*,*trans*-10,12-octadecadienoic] and densipolic[6c] [(−)-12-hydroxy-*cis*,*cis*-9,15-octadecadienoic] acids and suggested the absolute configuration of lesquerolic[6b] [(+)-14-hydroxy-*cis*-11-eicosenoic] acid.[7] Our suggestion concerning lesquerolic acid was confirmed by its synthesis from ricinoleic [(+)-12-D-hydroxy-*cis*-9-octadecenoic] acid which unequivocally established the structure as (+)-14-D-hydroxy-*cis*-11-eicosenoic acid.[8]

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[1] Presented in part at the 150th National Meeting of the American Chemical Society, Atlantic City, N. J., Sept 13–17, 1965, Abstracts, p 26S.

[2] (a) T. P. Hilditch and P. N. Williams, "The Chemical Constitution of Natural Fats," 4th ed, John Wiley and Sons, Inc., New York, N. Y., 1964; (b) F. B. Shorland in "Chemical Plant Taxonomy," T. Swain, Ed., Academic Press Inc., New York, N. Y., 1963, p 253; (c) R. G. Powell and C. R. Smith, Jr., *Chem. Ind.* (London), 470 (1965); (d) R. G. Powell, C. R. Smith, Jr., C. A. Glass, and I. A. Wolff, *J. Org. Chem.*, **30**, 610 (1965).

[3] K. Serck-Hanssen, *Chem. Ind.* (London), 1554 (1958).

[4] C. D. Baker and F. D. Gunstone, *J. Chem. Soc.*, 759 (1963).

[5] G. J. Schroepfer, Jr., and K. Bloch, *J. Am. Chem. Soc.*, **85**, 3310 (1963); *J. Biol. Chem.*, **240**, 54 (1965).

[6] (a) C. R. Smith, Jr., T. L. Wilson, E. H. Melvin, and I. A. Wolff, *J. Am. Chem. Soc.*, **82**, 1417 (1960); (b) C. R. Smith, Jr., T. L. Wilson, T. K. Miwa, H. Zobel, R. L. Lohmar, and I. A. Wolff, *J. Org. Chem.*, **26**, 2903 (1961); (c) C. R. Smith, Jr., T. L. Wilson, R. B. Bates, and C. R. Scholfield, *ibid.*, **27**, 3112 (1962).

[7] T. H. Applewhite, R. G. Binder, and W. Gaffield, *Chem. Commun.*, 255 (1965). Others have since used similar methods and results[3-5] to establish absolute configurations of helenynolic[2d] [(−)-9-hydroxy-*trans*-10-octadecen-12-ynoic] acid as D [J. C. Craig, S. K. Roy, R. G. Powell, and C. R. Smith, Jr., *J. Org. Chem.*, **30**, 4342 (1965)]; (+)-9-hydroxy-10,12-octadecadienoic acid from *Calendula officinalis* L. and dimorphecolic acid[6a] as D [R. C. Bandami and L. J. Morris, *J. Am. Oil Chemists' Soc.*, **42**, 1119 (1965)]; and dimorphecolic acid[6a] as D, by mixture melting point only [C. Y. Hopkins and M. J. Chisholm, *Can. J. Chem.*, **43**, 3160 (1965)].

[8] (a) T. H. Applewhite, *Tetrahedron Letters*, 3391 (1965); (b) *ibid.*, 4160 (1965).

TABLE I

OPTICAL ROTATORY DISPERSION OF LONG-CHAIN HYDROXY ACID DERIVATIVES

Compd	Specific rotation [α] in deg at					λ_{min}, mμ	Concn, g/100 ml
	589 mμ	500 mμ	400 mμ	300 mμ	250 mμ		
Methyl 9-hydroxyoctadecanoate (I)	−0.17	−0.23	−0.37	−0.77	−1.24	−1.41 (240)	1.49
Methyl 12-hydroxyoctadecanoate (II)	−0.35	−0.48	−0.74	−1.48	−2.09	−2.17 (245)	1.89
Methyl 14-hydroxyeicosanoate (III)	−0.23	−0.36	−0.55	−1.08	−1.76	−2.29 (240)	2.79
α-Naphthylurethan of II (IV)	−3.54	−4.86	−6.88	...	...	−9.61 (340)	0.494
α-Naphthylurethan of I (V)	+0.82	+1.28	+2.47	...	...	+4.90 (340)	0.485
Methyl 9-methoxyoctadecanoate (VI)	...	...	−0.41	−0.60	−0.95	...	3.15
Methyl 12-methoxyoctadecanoate (VII)	...	+1.65	+2.38	+3.29	+4.88	+6.71 (235)	0.164
Methyl 14-methoxyeicosanoate (VIII)	...	...	+0.56	+1.43	+2.43	+3.24 (235)	4.32
Methyl 12-hydroxy-*cis*-9-octadecenoate (IX)	+7.1	+8.9	+14.9	+26.2	...[a]	−19.3 (212)	1.68
Methyl 12-methoxy-*cis*-9-octadecenoate (X)	+15.3	+21.4	+35.2	+81.0	+158	+688 (207)	0.327, 0.0327
Methyl 12-hydroxy-*trans*-9-octadecenoate (XI)	+5.7	+8.1	+12.7	+23.8	...[b]	+18.5 (212)	2.98, 0.298
Methyl 14-hydroxy-*trans*-11-eicosenoate (XII)	+5.3	+7.3	+11.2	+22.3	...[c]	+14.3 (213)	3.49, 0.349
Methyl 14-hydroxy-*cis*-11-eicosenoate (XIII)	+10.1	+14.4	+22.2	+37.7	...[d]	−39.4 (217)	1.776, 0.178
Methyl 12-methoxy-*trans*-9-octadecenoate (XIV)	+12.9	+21.2	+34.1	+78.8	+152	+405 (215)	0.425
Methyl 14-methoxy-*trans*-11-eicosenoate (XV)	+14.0	+19.0	+31.7	+73.6	+143	+246 (225)	0.394
Methyl 14-methoxy-*cis*-11-eicosenoate (XVI)	+14.1	+20.3	+34.4	+77.3	+148	+300 (220)	0.640
1,12-Dihydroxy-*cis*-9-octadecene (XVII)	+6.7	+9.4	+14.5	+26.1	...[e]	−18.2 (215)	1.65, 0.330
1,12-Dihydroxy-*trans*-9-octadecene (XVIII)	+6.0	+9.0	+14.3	+27.3	...[f]	−14.0 (212)	1.51, 0.302
Methyl 12-hydroxy-*cis,cis*-9,15-octadecadienoate (XIX)	...	−1.49	−4.71	−24.3	−99.2	−1490 (205)	2.016, 0.202
Methyl 9-hydroxy-*trans,trans*-10,12-octadecadienoate (XX)	+12.8	+20.4	+42.1	+158	...	+711 (255)	3.04, 0.304, 0.0304
Methyl 12-methoxy-*cis,cis*-9,15-octadecadienoate (XXI)	...	+8.96	+14.9	...[g]	+8.95	−50.7 (225)	0.335
Methyl 9-methoxy-*trans,trans*-10,12-octadecadienoate (XXII)	−12.6	−17.8	−30.8	−56.1	...[h]	+37.4 (250)	1.07, 0.107
Methyl 9-hydroxy-*cis*-12-octadecenoate (XXIII)	−1.17	−1.76	−2.54	−5.86	−15.6	−78.1 (210)	1.024
Methyl 14-hydroxy-*trans*-2-*cis*-11-eicosadienoate (XXIV)	+4.4	+7.3	+11.9	+21.0	+27.4	...	2.734
Methyl 9-methoxy-*cis*-12-octadecenoate (XXV)	...	−2.6	−4.4	−10.9	−24.0	−28.4 (245)	0.458

[a] Curve has point of inflection $[\alpha]_{255}$ +32.4° crossing 0 axis at 215 mμ. [b] Curve has point of inflection $[\alpha]_{245}$ +32.2° crossing 0 axis at 214 mμ. [c] Curve has point of inflection $[\alpha]_{235}$ +35.8° crossing 0 axis at 214 mμ. [d] Curve has point of inflection $[\alpha]_{275}$ +41.1° crossing 0 axis at 226 mμ. [e] Curve has point of inflection $[\alpha]_{250-260}$ +31.2° crossing 0 axis at 218 mμ. [f] Curve has point of inflection $[\alpha]_{240-245}$ +36.3° crossing 0 axis at 215 mμ. [g] Curve has point of inflection $[\alpha]_{280-300}$ +23.9° crossing 0 axis at 245 mμ. [h] Curve has point of inflection $[\alpha]_{275-285}$ −65.4° crossing 0 axis at 253 mμ.

Results and Discussion

In order to facilitate comparison of our results with the earlier absolute configuration studies,[3-5] we carried out our initial measurements[7] on the saturated methyl esters obtained from various naturally occurring unsaturated hydroxy acids. To permit some assessment of possible effects of structure on optical rotation, measurements were also carried out on methyl ethers and two α-naphthylurethans of the saturated methyl esters. The various unsaturated esters were then examined along with their methyl ethers in an attempt to elucidate the possible perturbations introduced by olefin groupings. To check on the effect of the carbomethoxy group, two methyl esters were reduced to alcohols, and the resulting unsaturated diols were compared with the parent compounds. The ORD data are listed in Table I. Representative examples of the various dispersion curves are shown in Figures 1–4.

The ORD curves for the saturated hydroxy acid esters (Figure 1) could be measured to only 240 mμ and plain curves only were obtained. The transition[9] that possibly is most important in giving rise to the optical activity of the saturated hydroxy fatty acids is n → σ* of the alcohol chromophore near 180 mμ. The longest wavelength absorption present in these compounds is the low-intensity n → π* transition of the ester chromophore near 210 mμ.[10] The separation of the carbomethoxy group from the asymmetric center in these compounds renders the possibility of perturbation by this chromophore extremely unlikely. Further it appears unlikely that the highly flexible acyclic compounds involved would be fixed in a conformation that would allow intramolecular perturbation of the hydroxyl asymmetric center by the ester transition.

Measurements on the α-naphthylurethans (V and IV) of I and II (Figure 2) could be conducted only to 340 mμ because of high absorbance and thus no conclusions can be drawn concerning the optical activity of these aromatic absorption bands.[11] Furthermore, the enantiomeric curves obtained for the α-naphthylurethan derivatives emphasize the danger in making stereochemical assignments to such derivatives on the basis of ORD data alone.

ORD curves of the methyl ethers[12] (VI, VII, and VIII) of the three saturated hydroxy acids (Figure 2) showed plain dispersion curves to 235–250 mμ. The most likely absorption controlling the optical rota-

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(9) C. N. R. Rao, "Ultraviolet and Visible Spectroscopy," Butterworth and Co. (Publishers) Ltd., London, 1961.

(10) W. D. Closson and P. Haug, *J. Am. Chem. Soc.*, **86**, 2384 (1964).

(11) For example, *cf.* L. Verbit, *ibid.*, **87**, 1617 (1965).

(12) All methyl ethers reported in this paper have been prepared according to M. Neeman, M. C. Caserio, J. D. Roberts, and W. S. Johnson, *Tetrahedron*, **6**, 36 (1959). This reaction (diazomethane in the presence of catalytic amounts of fluoroboric acid) has been shown to proceed with retention of configuration.

Table II

Effect of Lewis Acid on Optical Rotatory Dispersion Curves

Solution	Specific rotation [α] in deg at 589 mμ	500 mμ	400 mμ	300 mμ	250 mμ	Concn, g/100 ml
VII in cyclohexane	...	+0.60[a]	+0.65	+1.46	...	3.694
VII in cyclohexane [20% Al(i-C_4H_{10})$_3$]	−0.46	−0.58	−0.89	−1.20	...	11.65
XIV in cyclohexane	+15.7	+22.1	+38.4	+86.7	+174	3.438
XIV in cyclohexane [20% Al(i-C_4H_{10})$_3$]	−3.85	−5.89	−11.6	−24.9[b]	...	4.41

[a] At 450 mμ. [b] At 325 mμ.

tion is the ether oxygen transition[9] near 190 mμ, similar to that noted for the parent alcohols. It is not surprising that the alcohol group derivatives of methyl 9-hydroxyoctadecanoate (I) and 12-hydroxyoctadecanoate (II) differ in rotational characteristics even though the parent acids are of identical configuration. Although all of the compounds studied have high symmetry, methyl 9-hydroxyoctadecanoate (I) has the highest. Apparently small differences in the size or polarizability of the groups attached to the asymmetric carbon atom cause the differences noted for these compounds with the same absolute configuration.

Some suggestions as to the effects of etherification have been advanced by Salvadori, *et al.*,[13] who noted that complexing ethers with a Lewis acid such as triisobutylaluminum strongly decreases or suppresses the contribution of the ether chromophore to the optical rotation. In this manner they were able to assess whether this particular chromophoric system contributed positively or negatively. To investigate the reversal of rotations of the parent 12-hydroxystearate and 14-hydroxyeicosanoate in comparison with their respective methyl ethers, we have obtained ORD curves for methyl 12-methoxyoctadecanoate (VII) in cyclohexane alone and in the presence of excess triisobutylaluminum (Table II). The ORD curve of VII in cyclohexane was positive but in the presence of triisobutylaluminum it was almost identical with that of methyl 12-hydroxyoctadecanoate (II, Figure 1). This result indicates that the ether chromophore makes a positive rotatory contribution in VII and VIII. It was suggested[13] that the large differences observed are related more to electronic factors than to different conformational equilibria. Our results seem in agreement with this suggestion.

The ORD curves of the long-chain esters containing the β-hydroxyene system (IX, XI, XII, and XIII) are quite similar. Curve IX (Figure 3) is representative. The similarity of methyl ricinoleate's (IX) ORD curve to that of methyl ricinelaidate (XI) and the identity of methyl lesquerolate's (XIII) curve[14] to that of methyl 14-hydroxy-*trans*-11-eicosenoate (XII) show that the geometry of the double bond (whether *cis* or *trans*) has no observable effect on the ORD curves. The similarity of these four ORD curves to those of ricinoleoyl (XVII) and ricinelaidyl (XVIII) alcohols also indicates that the ester absorption band does not perturb the asymmetric center.

The compounds with isolated double bonds have ultraviolet absorption maxima in the 183–187-mμ region.[15] This absorption could account for the different curves exhibited by the saturated and monounsaturated hydroxy acids of similar configuration. Oxygenated substituents β to the olefinic bond have various effects on the ultraviolet absorption.[15] From the experimental identity of the ORD curves of the *cis*- and *trans*-eicosenoates and -octadecenoates down to *ca.* 210 mμ we can detect no differences, however, that can be correlated with the ultraviolet spectra. The unsaturation β,γ to the asymmetric carbon in these compounds contributes positively to the rotation at long wavelengths, and the ether chromophore also renders the ORD curve more positive.

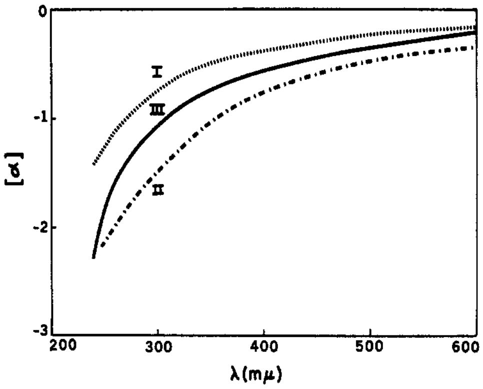

Figure 1.—Optical rotatory dispersion (methanol solution) of methyl 9-hydroxyoctadecanoate (I), methyl 12-hydroxyoctadecanoate (II), and methyl 14-hydroxyeicosanoate (III).

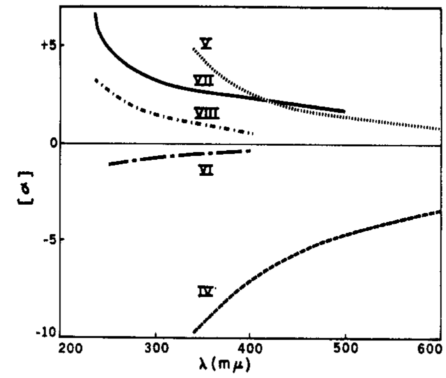

Figure 2.—Optical rotatory dispersion (methanol solution) of methyl 12-hydroxyoctadecanoate-α-naphthylurethan (IV), methyl 9-hydroxyoctadecanoate-α-naphthylurethan (V), methyl 9-methoxyoctadecanoate (VI), methyl 12-methoxyoctadecanoate (VII), and methyl 14-methoxyeicosanoate (VIII).

The results for the unsaturated compounds (XXIII and XXV) (Figure 3) are less clear. The unsaturation is γ,δ to the asymmetric center and is in the methyl-terminated chain in contradistinction to the β,γ-unsaturated compounds mentioned above. By comparison with the saturated derivative, methyl 9-hydroxy-

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[13] P. Salvadori, L. Lardicci, and P. Pino, *Tetrahedron Letters*, 1641 (1965).

[14] Smith, *et al.*,[5b] reported $[\alpha]^{22}D$ +6 ± 1° ($CHCl_3$) for lesquerolic acid. They noted the similarity to the rotation of ricinoleic acid and also suggested that lesquerolic acid is of the D configuration.

[15] R. G. Binder, L. A. Goldblatt, and T. H. Applewhite, *J. Org. Chem.*, **30**, 2371 (1965).

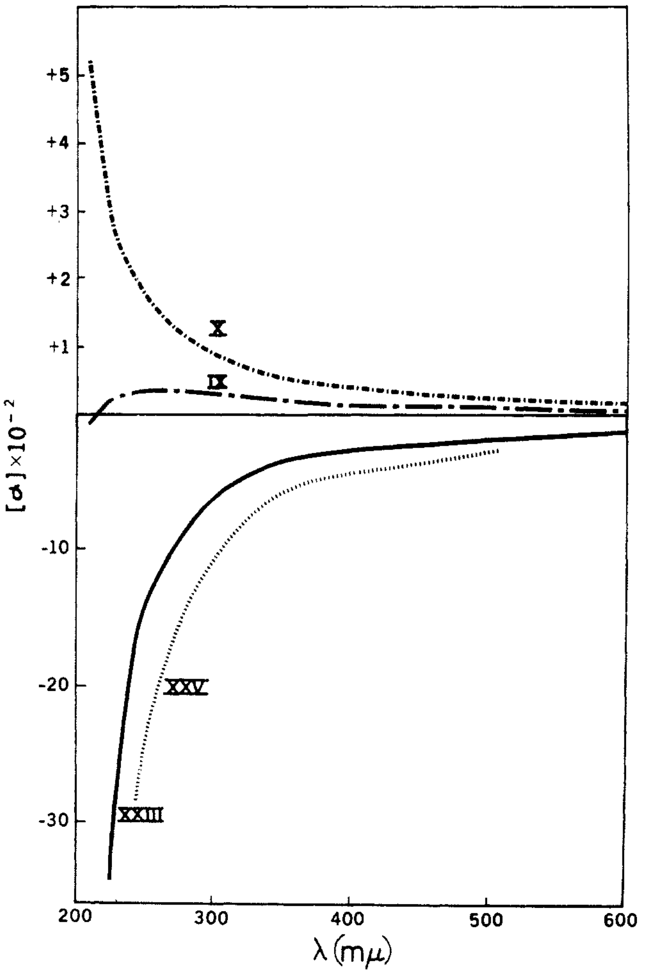

Figure 3.—Optical rotatory dispersion (methanol solution) of methyl 12-hydroxy-*cis*-9-octadecenoate (IX), methyl 12-methoxy-*cis*-9-octadecenoate (X), methyl 9-hydroxy-*cis*-12-octadecenoate (XXIII), and methyl 9-methoxy-*cis*-12-octadecenoate (XXV).

stearate (I), unsaturation appears to increase levorotation. The ether chromophore in (XXV) also increases levorotation at all measured wavelengths. In contrast to methyl ricinoleate, methyl 9-hydroxy-*cis*-12-octadecenoate does not change its sign of rotation below 250 mμ. This may result from additional separation of the olefinic bond from the oxygenated group and consequent different or lessened interaction.

A drastic change in the ORD curve of methyl 12-methoxyelaidate (XIV) in cyclohexane was noted upon addition of an excess of triisobutylaluminum (Table II). A negative plain curve was obtained which was more levorotatory at all wavelengths than that of the related saturated compound II. By analogy with other results[13] and our aforementioned experiments with ether VII, it is likely that the ether chromophore contribution is greatly diminished by complex formation. Complexing the Lewis acid with the double bond could influence its effect on the asymmetric center, possibly by reducing interaction between the two groups. The increased levorotation of the complexed methyl 12-methoxyelaidate (XIV) may result from conformational changes or dissymmetry induced by the complex.

The diunsaturated, long-chain hydroxy esters, methyl 12-hydroxy-*cis,cis*-9,15-octadecadienoate (densipolate, XIX) and methyl 9-hydroxy-*trans,trans*-10,12-octadecadienoate (dimorphecolate, XX), gave negative and positive plain curves, respectively, although they are of similar configuration (Figure 4). The diene system in XX is conjugated with the asymmetric center and has strong ultraviolet absorption at 231 mμ (ε 33,600);[16] thus, we were unable to make useful measurements in this region. Compound XIX has an isolated double bond in each alkyl side chain, but the absorption near 185 mμ could not be measured with our instrument. Reduction of XIX and XX gave (−)-II and (−)-I, respectively; thus, the asymmetric center was assigned[7] the D configuration in each of these diolefinic compounds.[17]

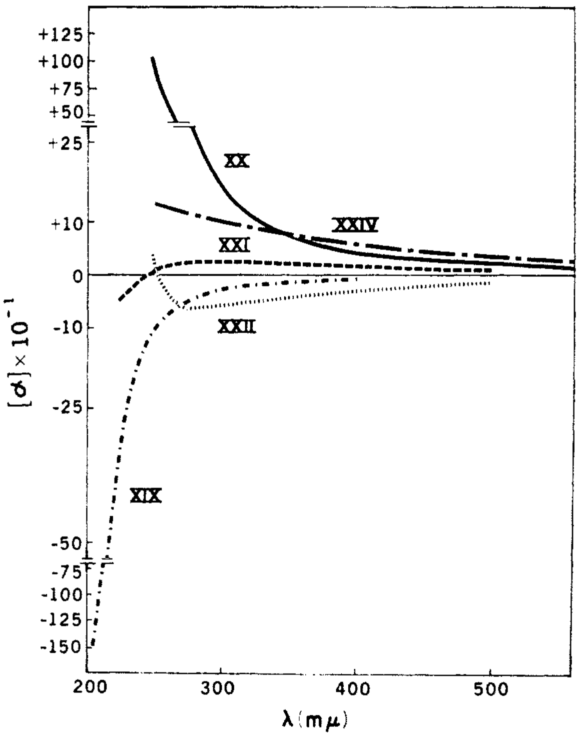

Figure 4.—Optical rotatory dispersion (methanol solution) of methyl 12-hydroxy-*cis,cis*-9,15-octadecadienoate (XIX), methyl 9-hydroxy-*trans,trans*-10,12-octadecadienoate (XX), methyl 12-methoxy-*cis,cis*-9,15-octadecadienoate (XXI), methyl 9-methoxy-*trans,trans*-10,12-octadecadienoate (XXII), and methyl 14-hydroxy-*trans*-2-*cis*-11-eicosadienoate (XXIV).

The different rotatory curves exhibited by the methyl ethers (Figure 4) XXI and XXII of XIX and XX in comparison with the parent alcohols probably result from complex electronic effects associated with these diunsaturated systems. The ORD of methyl 14-hydroxy-*trans*-2-*cis*-11-eicosadienoate (XXIV) is shown in Figure 4. This compound, which is an intermediate in the total synthesis of lesquerolic acid from ricinoleic acid,[8] has an α,β-unsaturated carboxylate chromophore which absorbs above 200 mμ. Within experimental error the ORD of this diunsaturated hydroxy acid ester is identical with that of methyl lesquerolate (XIII) providing an additional case showing the absence of rotatory effects of a remote chromophore upon the asymmetric center in the long-chain hydroxy acids.

The results of application of Brewster's conformational dissymmetry rule[18] to the long-chain hydroxy

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[16] M. J. Diamond, R. E. Knowles, R. G. Binder, and L. A. Goldblatt, *J. Am. Oil Chemists' Soc.*, **41**, 430 (1964).

[17] Smith, *et al.*,[6c] noted that XIX appeared to be optically inactive in methanol, but suggested that it has the D configuration by mixture melting point. With others,[6a] Smith reported that XX had $[\alpha]^{25}D$ +5° (CHCl$_3$), but its absolute configuration was not suggested.

[18] J. H. Brewster, *J. Am. Chem. Soc.*, **81**, 5475 (1959).

TABLE III

OPTICAL ROTATION ($[\alpha]^{27}$D, DEG) OF SOME LONG-CHAIN HYDROXY ACID METHYL ESTERS

Compd	Calcd[a]	Obsd[b]
I	...	−0.17
II	−0.3	−0.35
III	−0.3	−0.23
IX	+4.4	+7.1
XIII	+4.4	+4.7
XIX	+1.1	−0.58[c]
XXIII	−3.0	−1.2

[a] *Cf.* Reference 18. [b] *Cf.* Table I. [c] R. G. Binder and A. Lee, *J. Org. Chem.*, **31**, 1477 (1966).

acids are shown in Table III. Many of these compounds either were not available or were of unknown configuration at the time the rule was formulated. The predicted sign and magnitude of rotation for the methyl esters of 12-hydroxystearic acid (II) and 14-hydroxyeicosanoic acid (III) showed excellent agreement with the values observed. A calculated value for methyl 9-hydroxystearate (I) was not included since the different radical rotations can not be accurately estimated for this highly symmetrical compound. Further agreement between calculated and observed rotations has been found for all monounsaturated hydroxy acids (see Table II), both the sign and magnitude of rotation being correct. The conformational dissymmetry rule predicted the incorrect sign of rotation for methyl densipolate (XIX), although the correct sign of rotation was predicted for the methyl ether (XXI) of this compound. The discrepancy is not clear, because the predictions should be the same for the alcohols and their methyl ethers in all cases. We have not observed any marked changes in sign or magnitude of rotation of the various alcohols and their ethers in solvents of differing polarity. Thus, this would not seem to explain the one exception to Brewster's rules.[19] Caution should be exercised in applying these rules to compounds with very low $[\alpha]$D values. Solvent effects or small experimental errors could cause erroneous assignments of absolute configuration. From our results, however, it should be a relatively simple matter to employ ORD to determine the absolute configuration about the hydroxyl bearing carbon atom of most known long-chain hydroxy acids and of similar compounds isolated in the future. The absolute configurations of 9-hydroxyoctadecanoic,[4,5] 10-hydroxyoctadecanoic,[5] 12-hydroxyoctadecanoic,[3] 14-hydroxyeicosanoic,[8] and 17-hydroxyoctadecanoic[20] acids are known.[21] If the reduction product of an unsaturated, long-chain hydroxy acid is one of the above-mentioned saturated fatty acids, one needs only to determine its direction of rotation in order to assign absolute configuration, dextrorotatory corresponding to L and levorotatory to D configurations. As the configuration of the hydroxyl-bearing carbon is determined for other saturated fatty acids, they then may serve as configurational models for unsaturated compounds. Examination of the reduced hydroxy acid is necessary for configurational determination because unsaturated compounds of identical configuration may possess quite different ORD curves as shown in Figure 4 for methyl densipolate (XIX) and methyl dimorphecolate (XX).

Experimental Section[22]

Optical Rotatory Dispersion.—ORD measurements were performed on a Cary Model 60 recording spectropolarimeter. Path lengths of 0.1, 1, and 10 cm were used, and freshly distilled methanol was the solvent for all measurements unless otherwise noted. All measurements were made at 27°. The calibration and operation of our instrument have been reported.[23]

Analytical Procedures.—Infrared spectra were determined on a Perkin-Elmer Infracord Model 137 spectrophotometer. Ultraviolet spectra of cyclohexane solutions were determined with an extended-range Beckman Model DK-2 spectrophotometer as described.[15] Sample purity was checked by tlc analysis on silica gel and by glpc analyses on Apiezon L and ECNSS-S columns. Melting points were taken in capillary tubes in an electrically heated block and are uncorrected.

Methyl 12-Hydroxy-*cis*-9-octadecenoate (Ricinoleate, IX).—Methyl ricinoleate was isolated from mixed castor oil methyl esters by chromatography on silicic acid.[24]

Methyl 12-Hydroxy-*cis,cis*-9,15-octadecadienoate (Densipolate, XIX).—This hydroxy acid ester was prepared as described.[15]

Methyl 14-Hydroxy-*cis*-11-eicosenoate (Lesquerolate, XIII).—Methyl lesquerolate[6b] was prepared by distillation of mixed methyl esters of *Lesquerella fendleri* oil.[16]

Methyl 9-Hydroxy-*trans,trans*-10,12-octadecadienoate (Dimorphecolate, XX).—Methyl dimorphecolate[6a] was isolated from mixed methyl esters of *Dimorphotheca sinuata* oil by chromatography on silicic acid.[25]

Methyl 12-Hydroxy-*trans*-9-octadecenoate (Ricinelaidate, XI).—Methyl ricinelaidate was prepared as described by McCutchon, *et al.*[26] The infrared maximum was at 10.31 μ (*trans*-monoene).

Methyl 14-Hydroxy-*trans*-11-eicosenoate (XII).—Nitrous acid isomerization of methyl lesquerolate (XIII) gave methyl 14-hydroxy-*trans*-11-eicosenoate. After crystallization from commercial pentane and from 1:1 acetone-water, the ester had mp 47.5–48.5°. An infrared maximum was observed at 10.28 μ (*trans*-monoene).

Methyl 9-Hydroxyoctadecanoate (I).—Hydrogenation of methyl dimorphecolate (XX) and recrystallization of the product from commercial pentane gave I, mp 51.5–52.8° (lit. mp 49–51°,[6a] 53.0–53.5°[5]).

Methyl 12-Hydroxyoctadecanoate (IIa).—Hydrogenation of methyl ricinoleate (X) and recrystallization of the product from acetone gave methyl 12-hydroxyoctadecanoate, mp 56.8–57.8° (lit.[3] mp 57.5–58°).

IIb.—Hydrogenation of methyl densipolate[6c] (XIX) and crystallization of the product from commercial pentane gave IIb, mp 57.2–57.8° (lit.[6c] mp 56.0–56.5°). Mixture melting point with IIa was 56.9–57.6°.

Methyl 14-Hydroxyeicosanoate (III).—Hydrogenation of methyl lesquerolate[6b] (XIII) and crystallization of the product from acetone gave III, mp 59.5–61.0° (lit.[6b] mp 56–59°).

α-Naphthylurethan of II (IV).—Compound IIa (1.5 g, 0.0048 mole) in 25 ml of petroleum ether (bp 90–100°) was allowed to react with 0.8 ml (*ca.* 0.005 mole) of α-naphthyl isocyanate and 5 drops of triethylamine. The mixture was heated on the steam bath for 1 hr and allowed to stand overnight. Excess

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[19] Apparently there are exceptions to these observations. R. G. Powell (private communication) has pointed out that methyl 7-hydroxy-*trans,trans*-10,16-heptadecadien-8-ynoate[2c] has $[\alpha]^{25}$D −1.19° in cyclohexane and $[\alpha]^{25}$D +4.51° in methanol with both ORD curves becoming more positive at shorter wavelengths.

[20] P. A. J. Gorin, J. F. T. Spencer, and A. P. Tulloch [*Can. J. Chem.*, **39**, 846 (1961)] have assigned the L configuration to dextrorotatory 17-hydroxystearic acid on the basis of rotational data.

[21] It should be emphasized that the configurations of 9-,[4,5] 10-,[5] and 12-hydroxystearic[3] and 14-hydroxyeicosanoic[8] acids have been unequivocally determined. The assignment of configuration to (+)-17-hydroxystearic acid on a rotational basis[20] is not unequivocal. However, it would seem that the assignment is reasonably certain owing to the known model systems used for comparison.

[22] Reference to a company or product name does not imply approval or recommendation of the product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

[23] Y. Tomimatsu and W. Gaffield, *Biopolymers*, **3**, 509 (1965).

[24] R. G. Binder, T. H. Applewhite, G. O. Kohler, and L. A. Goldblatt, *J. Am. Oil Chemists' Soc.*, **39**, 513 (1962).

[25] R. G. Binder, T. H. Applewhite, M. J. Diamond, and L. A. Goldblatt, *ibid.*, **41**, 108 (1964).

[26] M. A. McCutchon, R. T. O'Connor, E. F. DuPré, L. A. Goldblatt, and W. G. Bickford, *ibid.*, **36**, 115 (1959).

isocyanate was decomposed with water, the solvent was evaporated and the product was extracted with hot petroleum ether (bp 60–70°). On cooling the extract 0.735 g of white solid was obtained, mp 60.1–61.0°. Recrystallization from methanol gave 0.665 g of solid, mp 60.5–61.2°.

Anal. Calcd for $C_{30}H_{45}NO_4$: C, 74.49; H, 9.38. Found: C, 74.3; H, 9.27.

This material, slightly impure as assessed by tlc, was chromatographed on a silica gel column using petroleum ether (bp 60–80°)–diethyl ether to gain a pure sample (tlc) for ORD measurements.

α-Naphthylurethan of I (V).—This compound was prepared from 1.28 g (0.004 mole) of I and excess isocyanate as above. The crude product did not readily crystallize and contained I as assessed by tlc. The crude product was chromatographed as before and recrystallized from commercial hexane several times with difficulty. Various melting points (*e.g.*, 31–32°, 41–42.5°) were obtained indicating that the compound apparently was polymorphic although it appeared pure by tlc.

Anal. Calcd for $C_{30}H_{45}NO_4$: C, 74.49; H, 9.38. Found: C, 74.4; H, 9.47.

Methyl Ethers of Hydroxy Acid Methyl Esters.—Reaction of the pure hydroxy acid methyl esters with diazomethane in the presence of fluoroboric acid[12] gave the corresponding methoxy derivatives. Chromatography on silicic acid separated products from starting materials. Characteristics of these compounds—all liquids at room temperature—are as follows.

Methyl 9-Methoxyoctadecanoate (VI).—Methylation of I led to a product with a maximum at 9.12 μ (ether). *Anal.* Calcd for $C_{20}H_{40}O_3$: C, 73.11; H, 12.27. Found: C, 73.3; H, 12.3.

Methyl 12-Methoxyoctadecanoate (VII).—A sample prepared from IIa solidified at −30° in an acetone–Dry Ice bath. When warmed it had mp 0.2–1.1°. This ester had an infrared maximum at 9.10 μ (ether).

Methyl 14-Methoxyeicosanoate (VIII).—The product has a maximum at 9.09 μ (ether). *Anal.* Calcd for $C_{22}H_{44}O_3$: C, 74.10; H, 12.44. Found: C, 74.3; H, 12.5.

Methyl 12-Methoxy-*cis*-9-octadecenoate (X).—A sample solidified at −60°. When slowly warmed in an acetone–Dry Ice bath it had mp −25.6 to −25.3°. The infrared spectrum has a maximum at 9.10 μ (ether).

Methyl 12-Methoxy-*trans*-9-octadecenoate (XIV).—A sample solidified at −60°. When slowly warmed in an acetone–Dry Ice bath it had mp −15.2 to −15.0°. It shows infrared maxima at 9.11 (ether) and 10.33 μ (*trans*-monoene).

Methyl 12-Methoxy-*cis*,*cis*-9,15-octadecadienoate (XXI).—The infrared spectrum of the ester has a maximum at 9.09 μ (ether); its ultraviolet spectrum showed λ_{max} 185.0 mμ (ε 25,200).

Anal. Calcd for $C_{20}H_{36}O_3$: C, 74.02; H, 11.18. Found: C, 74.1; H, 11.3.

Methyl 14-Methoxy-*cis*-11-eicosenoate (XVI).—The product has a maximum at 9.09 μ (ether). *Anal.* Calcd for $C_{22}H_{42}O_3$: C, 74.52, H, 11.94. Found: C, 74.7; H, 11.8.

Methyl 14-Methoxy-*trans*-11-eicosenoate (XV).—The ester has maxima at 9.09 (ether) and 10.28 μ (*trans*-monoene). *Anal.* Calcd for $C_{22}H_{42}O_3$: C, 74.52; H, 11.94. Found: C, 74.7; H, 12.0.

Methyl 9-Methoxy-*trans*,*trans*-10,12-octadecadienoate (XXII).—The product has strong maxima at 9.02 and 9.17 (ether), and 10.07 (*trans*,*trans*-conjugated diene), and weak maxima at 6.05 and 10.60 μ. The ultraviolet spectrum shows λ_{max} 231 mμ (ε 31,250). *Anal.* Calcd for $C_{20}H_{36}O_3$: C, 74.02; H, 11.18. Found: C, 74.0; H, 11.2.

***cis*-9-Octadecene-1,12-diol (Ricinoleoyl Alcohol, XVII).**—Methyl ricinoleate was reduced with lithium aluminum hydride. After the unreacted ester was saponified, acid salt and alcohol were partitioned between aqueous alkali and ether. Ricinoleoyl alcohol recovered from the ether layer showed one relatively nonpolar impurity which was removed by column chromatography on silica gel.

***trans*-9-Octadecene-1,12-diol (Ricinelaidyl Alcohol XVIII).**—The sample of ricinelaidyl alcohol,[27] mp 51.2–52.4°, was a gift from L. A. Goldblatt.

Methyl 14-Hydroxy-*trans*-2-*cis*-11-eicosadienoate (XXIV).—The tetrahydropyranose ether of this ester[8] was heated at 70° with methanol containing a trace of concentrated hydrochloric acid. The crude product was purified on a silica gel column with commercial hexane–diethyl ether to yield a single product as assessed by tlc. Infrared and nmr spectra were consistent with this structure.

Anal. Calcd for $C_{21}H_{38}O_3$: C, 74.51; H, 11.31. Found: C, 74.5; H, 11.3.

Methyl 9-Hydroxy-*cis*-12-octadecenoate (XIII).—After saponification of 950 mg of *Strophanthus kombe* seed oil and removal of nonsaponifiables, 880 mg of mixed fatty acids was recovered and esterified with methanolic hydrochloric acid. Chromatography of the esters on a silicic acid column gave a 142-mg fraction of methyl 9-hydroxy-*cis*-12-octadecenoate.[28] The sample showed only a single component on glpc and had a mass spectrum consistent with this structure.

Methyl 9-Methoxy-*cis*-12-octadecenoate (XXV).—The reaction of XXIII with diazomethane in the presence of fluoroboric acid[12] gave methyl 9-methoxy-*cis*-12-octadecenoate. This was purified by chromatography on silicic acid. The purified ester [λ_{max} 183.5 mμ (ε 13,200) in cyclohexane] showed only one peak on glpc and had ether absorption in the infrared at 9.13 μ.

Registry No.—I, 6114-37-0; II, 6114-39-2; III, 6114-38-1; IV, 7705-94-4; V, 7705-95-5; VI, 7705-96-6; VII, 7705-97-7; VIII, 7705-98-8; IX, 7705-99-9; X, 7706-00-5; XI, 7706-01-6; XII, 7706-02-7; XIII, 4102-96-9; XIV, 7781-97-7; XV, 7706-05-0; XVI, 7706-06-1; XVII 7706-07-2; XVIII, 7706-08-3; XIX, 6114-36-9; XX, 6114-34-7; XXI, 7706-10-7; XXII, 7706-11-8; XXIII, 10026-39-8; XXIV, 7721-86-0; XXV, 7706-13-0.

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(27) M. A. McCutchon, R. T. O'Connor, E. F. DuPré, L. A. Goldblatt, and W. G. Bickford, *J. Am. Oil Chemists' Soc.*, **36**, 450 (1959).

(28) F. D. Gunstone, *J. Chem. Soc.*, 1274 (1952).