Anal. Found: C, 49.98; H, 4.97; N, 26.56.

9-(1,5-Anhydro-2,3-dideoxy-D-*arabino*-hex-1-enitol-3-yl)adenine (XX) and 9-(1,5-Anhydro-2,3-dideoxy-D-*ribo*-hex-1-enitol-3-yl)-adenine (XXI).—A mixture of XX and XXI (1.6 g) obtained as described in the preparation of XVIII was applied to a Dowex AG 1X8 200–400 mesh column (OH form; 19 × 5.5 in.). Elution of the column with 50% aqueous methanol gave after concentration and crystallization from ethanol 0.67 g of XXI, mp 219–220, uv $\lambda_{max}^{pH\ 1}$ 258 nm (ϵ 15,200), $\lambda_{max}^{pH\ 11}$ 260 nm (ϵ 15,600), λ_{max}^{EtOH} 260 nm (ϵ 15,400), and 0.69 g of XX, mp 198–201°, uv $\lambda_{max}^{pH\ 1}$ 258 nm (ϵ 15,200), $\lambda_{max}^{pH\ 11}$ 260 nm (ϵ 15,600), λ_{max}^{EtOH} 260 nm (ϵ 15,400).

Anal. Found for XXI: C, 50.20; H, 5.00; N, 26.49. Found for XX: C, 49.95; H, 5.03; N, 26.63.

9-(2,3-Dideoxy-α-D-*erythro*-hexopyranosyl)adenosine (XXIV).—9-(2,3-Dideoxy-α-D-*erythro*-hex-2-enopyranosyl)adenine (XVIII) (200 mg, 0.8 mmol) was dissolved in 50 ml of water. To this solution was added 100 mg of 10% Pd/C and the mixture was then shaken with hydrogen at 45 psi and room temperature for 8 hr. The Pd/C was removed by filtration through a Celite bed, the Celite bed was washed with 50 ml of hot water, and the combined filtrates were evaporated *in vacuo* to a residue. The residue was crystallized from ethanol–water to give 100 mg of XXIV: mp 236–237°; uv $\lambda_{max}^{pH\ 1}$ 257 nm (ϵ 14,300); $\lambda_{max}^{pH\ 11}$ 260 nm (ϵ 14,900); $\lambda_{max}^{H_2O}$ 260 nm (ϵ 15,700).

Anal. Calcd for $C_{11}H_{15}N_5O_3$: C, 49.80; H, 5.69; N, 26.40. Found: C, 49.62; H, 5.61; N, 26.56.

9-(2,3-Dideoxy-β-D-*erythro*-hexopyranosyl)adenine (XXIII).—Hydrogenation of 9-(2,3-dideoxy-β-D-*erythro*-hex-2-enopyranosyl)adenine (XIX) (100 mg, 0.4 mmol) for 6 hr as in the procedure for XXIV gave after crystallization from ethanol 60 mg of XXIII: mp 218.5–219.5° dec; uv $\lambda_{max}^{pH\ 1}$ 256 nm (ϵ 11,800); $\lambda_{max}^{pH\ 11}$ 258 nm (ϵ 12,300); $\lambda_{max}^{H_2O}$ 258 nm (ϵ 12,200).

Anal. Calcd for $C_{11}H_{15}N_5O_3$: C, 49.80; H, 5.69; N, 26.40. Found: C, 49.77; H, 5.49; N, 26.55.

9-(1,5-Anhydro-2,3-dideoxy-D-*arabino*-hexitol-3-yl)adenine (XXII).—Hydrogenation of 9-(1,5-anhydro-2,3-dideoxy-D-*arabino*-hex-1-enitol-3-yl)adenine (XX) (200 mg, 0.8 mmol) as in the procedure for XIV gave after crystallization from ethanol 120 mg of XXII: mp 233–235°; uv $\lambda_{max}^{pH\ 1}$ 257 nm (ϵ 14,400); $\lambda_{max}^{pH\ 11}$ 260 nm (ϵ 14,700); $\lambda_{max}^{H_2O}$ 260 nm (ϵ 14,700).

Anal. Calcd for $C_{11}H_{15}N_5O_3 \cdot {}^1/_4H_2O$: C, 48.17; H, 5.88; N, 25.53. Found: C, 48.15; N, 5.60; N, 25.73.

Registry No.—III, 20787-44-4; IV, 35667-23-3; V, 35667-24-4; VI, 35667-25-5; VII, 20789-68-8; VIII (manno), 35667-27-7; VIII (allo), 35667-28-8; IX, 35666-84-3; XI, 30624-97-6; XII, 31654-90-7; XIII, 35666-86-5; XIV, 35666-87-6; XV, 35667-29-9; XVI, 35667-30-2; XVII, 35667-31-3; XVIII, 35666-83-2; XIX, 35737-21-4; XXI, 35657-25-1; XXII, 35657-26-2; XXIII, 35657-27-3; XXIV, 35657-28-4; 2-acetamido-6-chloropurine, 7602-01-9.

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The Absolute Configuration of Methyl 3-*O*-Acetyl-2,3-dihydroxy-2-methylpropanoate by Nuclear Magnetic Resonance and Chemical Determination

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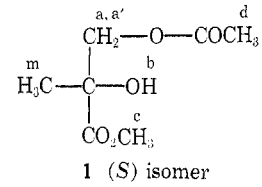
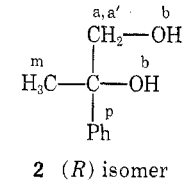
The chemical transformation of (*S*)-(+)-atrolactic acid to methyl 3-*O*-acetyl-(*R*)-2,3-dihydroxy-2-methylpropanoate (1), $[\alpha]^{23}D$ −9.5°, gives an absolute configuration in agreement with the prediction from solvate models and the sense of nonequivalence apparent in the nmr spectra of 1 in the solvent (*R*)-1-(1′-naphthyl)ethylamine.

A study of the Grignard reaction with optically active carbonyl compounds, being carried out in this laboratory, yields products of unknown stereochemistry, whose absolute configuration can be determined most conveniently by degradation to an enantiomer of α-methylglyceric acid. The resolution of α-methylglyceric acid (2,3-dihydroxy-2-methylpropanoic acid) was attempted without success by Glattfield and Sherman.[2] Preparation and assignment of the absolute configuration of methyl 3-*O*-acetyl-2,3-dihydroxy-2-methylpropanoate (1) (Table I) is described herein. Two methods of assignment were used: chemical transformation of (*S*)-(+)-atrolactic acid of known absolute configuration[3] to methyl 3-*O*-acetyl-(*R*)-2,3-dihydroxy-2-methylpropanoate, *via* reactions remote from the asymmetric center; and establishment of a consistent pattern between the sense of nonequivalence apparent in the nmr spectra of methyl 3-*O*-acetyl-(*R*)-2,3-dihydroxy-2-methylpropanoate and its enantiomer in the solvent (*R*)-1-(1′-naphthyl)ethylamine with predictions based on solvate models.

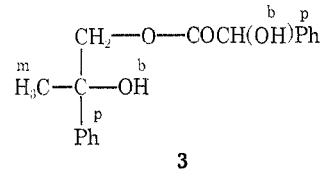
Atrolactic acid was prepared by the method of Eliel and Freeman[4] and partially resolved as the quinine salt using the procedure of McKenzie and Clough.[5] The partially resolved (*S*)-atrolactic acid was then reduced by lithium aluminum hydride to (*S*)-(+)-



1 (*S*) isomer



2 (*R*) isomer



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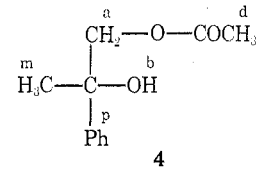

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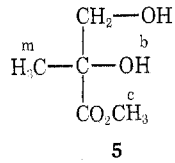

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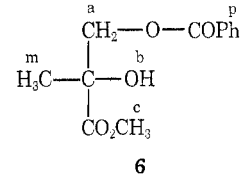

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(1) Taken from the Ph.D. Dissertation of Fred L. Shore.

(2) J. W. E. Glattfeld and L. P. Sherman, *J. Amer. Chem. Soc.*, **47**, 1742 (1925).

(3) J. H. Brewster, *ibid.*, **78**, 4061 (1956).

(4) E. L. Eliel and J. P. Freeman, *Org. Syn.*, **33**, 7 (1953).

(5) A. McKenzie and G. W. Clough, *J. Chem. Soc.*, **97**, 1016 (1910).

TABLE I

NUCLEAR MAGNETIC RESONANCE SPECTRA[a] OF DERIVATIVES OF 1,2-PROPANEDIOL

Compd	Chemical shifts, ppm							Coupling constants
	H_p	H_m	H_a	$H_{a'}$	H_b	H_c	H_d	$J_{a,a'}$, Hz
Methyl 3-*O*-acetyl-2,3-dihydroxy-2-methylpropanoate (**1**)		1.40	4.32	4.09	3.65	3.79	2.03	11.2
2-Phenyl-1,2-propanediol (**2**)	7.45	1.42	3.75	3.49	3.10			11.0
1-*O*-((2′*R*)-Mandeloyl)-(2*S*)-2-phenyl-1,2-propanediol (**3**)	7.23	1.36	4.24		2.69 5.07			
1-*O*-Acetyl-2-phenyl-1,2-propanediol (**4**)	7.5	1.59	4.31		2.65		2.07	
2,3-Dihydroxy-2-methylpropanoate (**5**)		1.36	3.80	3.56	2.96	3.81		11.7
Methyl 2-*O*-benzoyl-2,3-dihydroxy-2-methylpropanoate (**6**)	7.6	1.48	4.42		3.63	3.79		
4 in (*R*)-1-(1′-naphthyl)ethylamine and $CFCl_3$	7.41	1.46	4.23				1.76 (*S*), 1.74 (*R*)	
1 in (*R*)-1-(1′-naphthyl)ethylamine and $CFCl_3$		1.34	4.20			3.50	1.79 (*R*), 1.78 (*S*)	
75% op[c] (*R*)-**4** in (*R*)-1-(1′-naphthyl)-ethylamine and $CFCl_3$, 100 MHz[b]	7.39	1.46	4.19				1.81 (*S*), 1.79 (*R*)	
77.1% op[c] (*R*)-**1** in (*R*)-1-(1′-naphthyl)-ethylamine and $CFCl_3$, 100 MHz[b]		1.32	4.21			3.48	1.80 (*R*), 1.79 (*S*)	

[a] At 60 MHz in $CDCl_3$ at 30° unless indicated. [b] Chemical shifts are concentration and temperature dependent. [c] Optically pure.

2-phenyl-1,2-propanediol (**2**), whose optical purity was 77.1% by comparison with the rotation reported by Eliel and Freeman for the optically pure compound.[6]

(*S*)-(+)-2-Phenyl-1,2-propanediol was also obtained from α-methylstyrene. α-Methylstyrene was converted to α-methylstyrene oxide *via* the bromohydrin as described by Eliel and Rerick.[7] (*R*)-Mandelic acid opening of α-methylstyrene oxide gave the expected mixture of diastereomers from which 1-*O*-((2′*R*)-mandeloyl)-(2*S*)-2-phenyl-1,2-propanediol (**3**) was separated by fractional crystallization. The assignment of the mandeloyl group to the terminal position of this half-ester was based on the nmr spectral chemical shift of the methylene protons (δ 4.24) *vs.* the chemical shift of the methylene protons of 2-phenyl-1,2-propanediol (average δ 3.50) and on the mass spectral base peak at *m/e* 121 derived from α cleavage of the bond between the carbons containing oxygen in the substituted glycol. The mandelate half-ester was treated with a catalytic amount of sodium in an excess of methanol to give, after chromatography, (*S*)-2-phenyl-1,2-propanediol of 97.5% optical purity. By this procedure, the (*R*)-2-phenyl-1,2-propanediol of 75.1% optical purity was obtained by using (*S*)- instead of (*R*)-mandelic acid to effect epoxide ring opening.

Acetylation of DL-2-phenyl-1,2-propanediol with acetic anhydride in pyridine gave the primary acetate (by nmr and mass spectrum), 1-*O*-acetyl-DL-2-phenyl-1,2-propanediol (**4**). This reaction was repeated with the two samples of (*S*)-2-phenyl-1,2-propanediol (**2**) of 77.1 and 97.5% optical purity to give the respective crude acetates, which were ozonized in acetic acid. The crude acids were esterified with diazomethane and, after chromatographic purification, the rotations of the respective samples of crystalline methyl 3-*O*-acetyl-(*R*)-2,3-dihydroxy-2-methylpropanoate were determined. From these experimental rotations and the optical purities determined for the samples of **2** and assumed identical for the samples of the product **1**, optically pure methyl 3-*O*-acetyl-(*R*)-2,3-dihydroxy-2-methylpropanoate (**1**) is calculated to have $[\alpha]^{23}D$ −9.5°.

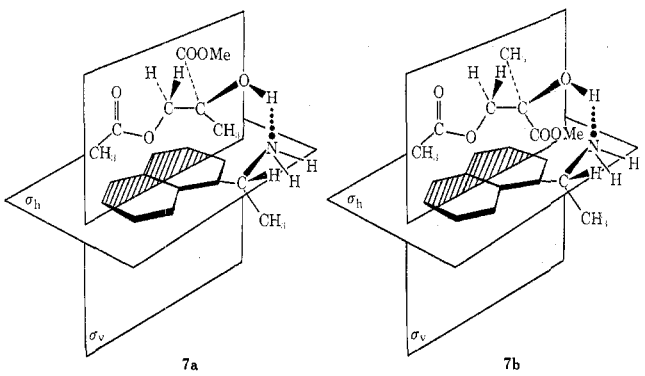
An independent synthesis of methyl 3-*O*-acetyl-DL-2,3-dihydroxy-2-methylpropanoate from methyl methacrylate confirmed the identity of this derivative of α-methylglyceric acid. Methyl methacrylate was hydroxylated with osmium tetroxide plus anhydrous hydrogen peroxide in *tert*-butyl alcohol to yield 2,3-dihydroxy-2-methylpropanoate (**5**). Treatment of this ester with acetic anhydride in pyridine gave methyl 3-*O*-acetyl-DL-2,3-dihydroxy-2-methylpropanoate having identical melting point and ir spectra with those of the optically inactive **1** obtained from the ozonolysis followed by esterification of **2**.

Pirkle and Beare[8] have shown that (*R*)-1-(1′-naphthyl)ethylamine is an excellent optically active solvent for many chiral alcohols, pertinently methyl esters of α-hydroxy acids. The protons of the ester methyl group were observed to have a sense of nonequivalence. However, methyl 2,3-dihydroxy-2-methylpropanoate (**5**) as well as all derivatives of this compound studied (**1** and **6**) did *not* show an observable sense of nonequivalence for the ester methyl protons. The solvent–solute models proposed by Pirkle and Beare[9a] need to be modified in order to explain the spectra of these compounds.

Methyl 2-*O*-acetyl-2,3-dihydroxy-2-methylpropanoate has a hydrogen attached to oxygen available for hydrogen bonding to the nitrogen of the (*R*)-1-(1′-naphthyl)ethylamine, but there are two carbonyl groups available for dipolar attraction with the naphthyl ring of the amine. The nmr spectra show that only the methyl protons of the acetyl group have a sense of nonequivalence, indicating that the carbonyl group of the acetyl is more strongly attracted to the naphthyl ring than the carbomethoxy portion of the molecule. The acetyl protons of the (*R*)- and (*S*)-1-*O*-acetyl-2-phenyl-1,2-propanediol enantiomers show a greater sense of nonequivalence (Δδ 0.9 Hz) in the nmr spectra in (*R*)-1-(1′-napththyl)ethylamine as

(6) E. L. Eliel and J. P. Freeman, *J. Amer. Chem. Soc.*, **74**, 923 (1952).
(7) E. L. Eliel and M. N. Rerick, *ibid.*, **82**, 1362 (1960).
(8) W. H. Pirkle and S. D. Beare, *Tetrahedron Lett.*, 2579 (1968).
(9) (a) W. H. Pirkle and S. D. Beare, *J. Amer. Chem. Soc.*, **91**, 5150 (1969); (b) T. Ledaal, *Tetrahedron Lett.*, 1683 (1968).

compared to the acetyl protons of (*R*)- and (*S*)-**1** ($\Delta\delta$ 0.6 Hz). This difference reflects the greater size of the phenyl group as compared to the carbomethoxy group.



7a **7b**

Two diastereomerically related solvate models (**7a** and **7b**) are the most probable for the two enantiomers of **1** (**7a** = *S*, **7b** = *R*) in (*R*)-1-(1′-naphthyl)ethylamine. In structures **7a** and **7b**, the naphthyl ring is in the σ_h plane, whereas the acetoxy group and carbons C-2 and C-3 of the methyl dihydroxypropanoate molecule are in the σ_v plane. The C=O σ-bond axis of the acetyl group is aligned perpendicular to the σ_h plane with the carbon atom nearer the naphthyl ring, as described by Pirkle and Beare[9a] and by Ledaal.[9b] Although the C=O orientation is fixed, sufficient flexibility exists for the remainder of the chain to freely assume one of several other possible conformations rather than be in the eclipsed one as shown in structures **7a** and **7b**. An examination of the diastereomeric solvate models leads to the prediction that the model with the methyl group pointing down toward the ring (**7a**) would allow a closer approach (stronger attraction) of the carbonyl group to the naphthyl ring than the model which shows the carbomethoxy group down (**7b**). These models lead to the prediction that the protons of the acetyl group of methyl 3-*O*-acetyl-(*S*)-2,3-dihydroxy-2-methylpropanoate in (*R*)-1-(1′-naphthyl)ethylamine (**7a**) would be more shielded (closer to the shielding portion of the aromatic ring) than the acetyl protons of the *R* enantiomer (**7b**). This prediction is in agreement with the nmr spectra of optically active **1** in (*R*)-1-(1′-naphthyl)ethylamine. In the 100-MHz nmr spectra of 77% optically pure (*R*)-**1** in (*R*)-1-(1′-naphthyl)ethylamine, the relative peak ratio for the acetyl proton of the *R* and *S* enantiomers was 878:122, respectively, from which an optical purity value of 75.6% was obtained.

Replacement of the carbomethoxy groups by phenyl groups in structures **7a** and **7b** provide the most probable solvate models for the *R* and *S* enantiomers of **4**, respectively. Again, the acetyl protons of the enantiomer with the methyl group down (as in **7a**), being more shielded by the naphthyl ring, should resonate at higher field than the enantiomer with the phenyl group down. This was found to be the case. The nmr spectrum of (*R,S*)-**4** in (*R*)-1-(1′-naphthyl)ethylamine at 50 sweepwidth on a 60-MHz instrument showed two distinct peaks of equal heights, one for each group of acetyl protons of the enantiomers. By adding a small amount of (*R*)-**4** to this *R,S* sample, the higher field peak height increased in the nmr spectrum. The 100-MHz nmr spectrum of 75% optically pure (*R*)-**4** showed peak heights ratio of 105:895 for the *S* and *R* enantiomers, respectively, from which an optical purity value of 79.0% was obtained. The deviation of these results from the polarimetric values are slightly greater than the errors reported by Pirkle and Beare[9a] for the nmr determination of the optical purity of amino acids. In part, the error is due to the rather small chemical shift difference ($\gtrsim$1 Hz) between the acetyl protons of the enantiomers such that as the abundance of one becomes predominant and the lesser component appears as a shoulder on the larger peak, which is sometimes difficult to measure.

Experimental Section[10]

Atrolactic Acid.—This compound was synthesized from acetophenone through the cyanohydrin by the method of Eliel and Freeman.[4] The instructions were followed with a lower yield obtained. Atrolactic acid is listed in the Aldrich Chemical Co. catalog but is apparently not currently commercially available.

Resolution of Atrolactic Acid.—The racemic atrolactic acid was resolved by fractional crystallization of its quinine salt, following the method of McKenzie and Clough.[5]

Reduction of (*S*)-Atrolactic Acid with Lithium Aluminum Hydride.—This reaction was performed by the method of Eliel and Freeman.[6] The product was not crystallized but chromatographed on 80 g of SilicAR CC-7;[11] the eluent was collected in 80-ml fractions. Fractions 1–8 were chloroform and 9–14 were 1:9 acetone:chloroform. Fractions 8–12 were shown to be the diol by thin layer chromatography with 1:1 chloroform–acetone and were combined and distilled at 0.40 Torr and an oil bath temperature of 120°. A 2.30-g sample of (*S*)-atrolactic acid gave 1.40 g of (*S*)-2-phenyl-1,2-propanediol, $[\alpha]^{23}D$ 6.89° (*c* 7.15, Et_2O). Comparison with the value obtained by Eliel and Freeman[5] of 8.94 ± 0.08° gives an optical purity of 77.1%. Also, the optical rotation of the diol was determined in ethanol, $[\alpha]^{23}D$ 7.28° (*c* 8.08, EtOH), from which the optically pure compound in this solvent was calculated to be $[\alpha]^{23}D$ 9.42°.

Anal. Calcd for $C_9H_{12}O_2$: C, 71.02; H, 7.95. Found: C, 70.89; H, 8.04.

α-Methylstyrene Oxide.—The method of Eliel and Rerick,[7] from α-methylstyrene *via* the bromohydrin, was followed to give the same yield of α-methylstyrene oxide, bp 54–57° (1.8 Torr) [lit. bp 62° (2.3 Torr)]. Caution! This product is a lachrymator. Gas chromatography at 100° showed only a trace of contaminates.

1-*O*-((2′*R*)-Mandeloyl)-(2*S*)-2-phenyl-1,2-propanediol.—A 15-g sample of (*R*)-mandelic acid was dissolved in 500 ml of chloroform. α-Methylstyrene oxide (13.5 g) was added and the solution was heated under reflux for 61 hr. The cooled solution was washed with an equal volume of 1 *M* aqueous potassium bicarbonate. After removal of the solvents *in vacuo* the resulting oil was crystallized from acetone–hexane. These crystals were recrystallized twice from ethanol–water to yield 3.06 g (10.7%) of white crystals, mp 101–102°. By substituting (*S*)-mandelic acid in this procedure, 1-*O*-((2′*S*)-mandeloyl)-(2*R*)-2-phenyl-1,2-propanediol was produced in comparable yields, $[\alpha]^{23}D$ 70.5° (*c* 6.54, EtOH), 75% optical purity.

(10) All melting points were taken on a Fisher-Johns melting point apparatus and are uncorrected. Boiling points are also uncorrected. Elemental analyses were performed by Midwest Microlabs, Inc., Indianapolis, Ind. All nmr spectra were obtained by Katie Reimer with a Varian A-60 instrument or by Dave O'Keeffe with a JEOL JNM-4H-100. The rotations were measured in a 2-dm capillary cell in a Rudolph 80 polarimeter. All gas chromatograms were obtained with an Aerograph Model A-350-B dual column thermal conductivity instrument with helium as the carrier gas and using an 8 ft × 0.25 in. o.d. copper column containing 5% XE-60 on less than 80 mesh ABS (Analab Inc., Hamden, Conn.). Thin layer chromatography was conducted on 1 × 3 in. glass plates covered with a layer of silicic acid, HF_{254} (Merck, Darmstadt, Germany), using the solvent system specified. Iodine vapor or uv light was used to detect compounds in the developed chromatograms. Ozone was produced by an OREC model 03C6 ozonizer. The mass spectra were obtained on an Atlas CH-4B at 70 eV by Richard Scott or Gene Kelley.

(11) Silicic acid, Mallinckrodt Chemical Works.

Anal. Calcd for $C_{17}H_{18}O_4$: C, 71.31; H, 6.34. Found: C, 71.40; H, 6.52.

(*S*)-2-Phenyl-1,2-propanediol from 1-*O*-((2′*R*)-Mandeloyl)-(2*S*)-2-phenyl-1,2-propanediol.—A 2.81-g sample of the ester was dissolved in 200 ml of anhydrous methanol. A few milligrams of sodium metal was added and the reaction was monitored by thin layer chromatography using 1:1 chloroform–acetone as the eluent. The starting material has an R_f of 0.45 compared with the products methyl mandelate, 0.57, and 2-phenyl-1,2-propanediol, 0.25. The reaction appeared complete after 1.5 hr but was allowed to remain at room temperature for 21.5 hr. After the reaction mixture was poured through 20 ml of methanol-washed Dowex 50 W-X8, the solution was evaporated and the resultant oil was chromatographed on 140 g of SilicAR CC-7. The first 19 fractions were 80 ml of chloroform each and later fractions 80 ml each of 1:9 acetone:chloroform. Fractions 21–24 contained the 2-phenyl-1,2-propanediol, 1.16 g (77.8%). After removal of the solvent the oil was distilled at 0.4 Torr and an oil bath temperature of 120°, $[\alpha]^{23}D$ 9.18° (*c* 8.13, EtOH). By comparison with the rotation calculated for the optically pure diol of 9.42, an optical purity of 97.5% is calculated for this sample. (2*R*)-2-Phenyl-1,2-propanediol of 75% optical purity, $[\alpha]^{23}D$ −7.05° (*c* 7.28, EtOH), was obtained by this procedure from 1-*O*-((2′*S*)-mandeloyl)-(2*R*)-2-phenyl-1,2-propanediol (Table II).

TABLE II

MASS SPECTRA OF 1-*O*-((2′*S*)-MANDELOYL)-(2*R*)-2-PHENYL-1,2-PROPANEDIOL

m/e	% of base peak	*m/e*	% of base peak
43	77	118	64
77	52	121	100
79	53	122	65
91	54	134	45
105	67	166	41
107	70	286 (M)	12

Anal. Calcd for $C_9H_{12}O_2$: C, 71.02; H, 7.95. Found: C, 70.96; H, 7.98.

2-Phenyl-1,2-propanediol from α-Methylstyrene.—The method of Milas and Sussman[12] was used. α-Methylstyrene (59 g, 0.5 mol) was dissolved in 272 ml of the anhydrous hydrogen peroxide–*tert*-butyl alcohol solution. After the addition of 20 mg of osmium tetroxide (caution, toxic) the solution was cooled in an ice bath for 1 hr. The color of the solution changes from yellow to orange to black. After 11 hr at room temperature, the solution tested negative to potassium iodide starch paper, the solvents were removed *in vacuo*, and the oil was distilled to yield 22.4 g (29.3%) of 2-phenyl-1,2-propanediol, bp 104–107° (0.45 Torr).

Methyl 2,3-Dihydroxy-2-methylpropanoate.—This compound was prepared by the same method as 2-phenyl-1,2-propanediol: a 20-g (0.2 mol) sample of methyl methacrylate in 100 ml of the hydrogen peroxide–*tert*-butyl alcohol solution plus 4.9 mg of osmium tetroxide, 19 hr total reaction time. Distillation gave 6.18 g (23.1%) of methyl 2,3-dihydroxy-2-methylpropanoate, bp 82–84° (0.65 Torr). A 2.0-g sample was chromatographed on 100 g of SilicAR CC-4 with acetone, 75-ml fractions. Fraction 3 was evaporated and distilled at 0.65 Torr (oil bath temperature 95°) to give 1.6 g of an oil. Crystallization of this oil from ether–hexane was unsuccessful and the vacuum distillation was repeated to give 1.5 g of methyl 2,3-dihydroxy-2-methylpropanoate.

Anal. Calcd for $C_5H_{10}O_4$: C, 44.77; H, 7.52. Found: C, 44.86; H, 7.56.

Methyl 3-*O*-Acetyl-2,3-dihydroxy-2-methylpropanoate from Methyl Methacrylate.—Osmium tetroxide hydroxylation of 10 g (0.1 mol) of methyl methacrylate with 50 ml of the hydrogen peroxide–*tert*-butyl alcohol solution plus 10 mg of osmium tetroxide was allowed to proceed for 24 hr. From this solution, after solvent removal, was obtained 6.77 g (38.5%) of a black tar. This tar was dissolved in 30 ml of anhydrous pyridine and cooled to 0°, and 30 ml of acetic anhydride was added. After 17 hr at room temperature the flask was cooled to 0° and 10 ml of water was added. The solvents were removed *in vacuo* and attempted crystallization from ether–hexane (after the solution was treated with Norite) was unsuccessful. The oil was chromatographed on 300 g of SilicAR CC-7 and eluted with 200-ml fractions of 6:4 chloroforom–Skellysolve B (fractions 1–11) and 7:3 chloroform–Skellysolve B (fractions 12–21). Gas chromatography at 190° showed that fractions 18–20 were methyl 3-*O*-acetyl-2,3-dihydroxy-2-methylpropanoate (2.13 g, 12.1% overall). Fraction 18 gave crystals (mp 48.5–49.5°) from ether–hexane.

Anal. Calcd for $C_7H_{12}O_5$: C, 47.72; H, 6.87. Found: C, 47.69; H, 6.95.

Methyl 3-*O*-Benzoyl-2,3-dihydroxy-2-methylpropanoate from Methyl Methacrylate.—By a procedure similar to that described for its acetate derivative, a 7.7-g sample of methyl methacrylate, 39 ml of hydrogen peroxide–*tert*-butyl alcohol solution, and 5 mg of osmium tetroxide were allowed to react for 26 hr. Solvent removal *in vacuo* yielded 5.4 g (38.9%) of crude 2,3-dihydroxy-2-methylpropanoate, which was dissolved in 25 ml of pyridine and cooled to 0°. To this cold solution, benzoyl chloride (5 ml) was added dropwise with swirling. The reaction mixture was allowed to warm to room temperature. After 10 hr a few drops of water and 75 ml of chloroform were added. The solution was washed in succession with 50-ml portion of water, once; 1 *N* aqueous hydrochloric acid, six times; 1 *M* aqueous potassium-bicarbonate, four times; and finally water, four times. Removal of the solvent *in vacuo* gave 8.71 g of crude product, which was chromatographed on 200 g of SilicAR CC-7. Elution was started with 7:3 chloroform–Skellysolve B (fractions 1–17), then 8:2 chloroform–Skellysolve B (fractions 18–24), and fractions 25–27 were chloroform. Fractions 1–22 were 80 ml and fractions 23–27 were 200 ml. Gas chromatography at 210° showed that fractions 21–24 were the product (2.14 g, 11.7% overall). Fractions 21–24 were combined and crystallized three times from ether–Skellysolve B to yield 0.66 g of methyl 3-*O*-benzoyl-2,3-dihydroxy-2-methylpropanoate, mp 66–67°.

Anal. Calcd for $C_{12}H_{14}O_5$: C, 60.50; H, 5.92. Found: C, 60.76; H, 6.10.

1-*O*-Acetyl-2-phenyl-1,2-propanediol.—A 2.0-g sample of 2-phenyl-1,2-propanediol was dissolved in 20 ml of anhydrous pyridine and cooled to 0°. Acetic anhydride (20 ml) was added. The solution was allowed to warm to room temperature and after 12 hr the solvents were removed *in vacuo*. The resulting yellow oil was chromatographed on 95 g of SilicAR CC-7. Fractions 1–3 were eluted by 80-ml portions of 6:4 chloroform–Skellysolve B. Fractions 4 and 5 were eluted by 100-ml portions of 7:3 chloroform–Skellysolve B, and fractions 6–11 were eluted by 80 ml of 8:2 chloroform–Skellysolve B. Thin layer chromatography with chloroform showed one spot (R_f 0.24) for fractions 7–11. Fractions 7–11 were concentrated *in vacuo* to yield 1.69 g of oil. This oil was distilled at 1.1 Torr with a pot temperature of 158° to yield 1.6 g (69.4%) of 1-*O*-acetyl-2-phenyl-1,2-propanediol. By this procedure both 1-*O*-acetyl-(2*R*)-2-phenyl-1,2-propanediol, $[\alpha]^{23}D$ 13.48 (*c* 8.17, EtOH), optical purity 75%, and 1-*O*-acetyl-(2*S*)-2-phenyl-1,2-propanediol, $[\alpha]^{23}D$ −13.54 (*c* 9.45, EtOH), optical purity 75%, were prepared.

Anal. Calcd for $C_{11}H_{14}O_3$: C, 68.02; H, 7.26. Found: C, 67.80; H, 7.37.

Nmr Spectra of Compounds in (*R*)-1-(1′-Naphthyl)ethylamine.—Following Pirkle and Beare[9a] the nmr spectra were obtained on samples with a mole ratio (*R*)-1-(1′-naphthyl)ethylamine:ester: fluorotrichloromethane of 2:1:3. These samples were prepared directly in the nmr sample tubes because of possible solubility differences of the enantiometers in the amine and because of the rapid reaction of the amine with carbon dioxide in the air to form an insoluble salt.

Methyl 3-*O*-Acetyl-(*R*)-2,3-dihydroxy-2-methylpropanoate from (*S*)-2-Phenyl-1,2-propanediol.—Samples of (*S*)-2-phenyl-1,2-propanediol from lithium aluminum hydride reduction of (*S*)-atrolactic acid (I) and from methanolysis of 1-*O*-((2′R)-mandeloyl-(2*S*)-2-phenyl-1,2-propanediol (II) were carried through the same procedure to yield samples I and II of methyl (2*R*)-2,3-dihydroxypropanoate. The (*S*)-2-phenyl-1,2-propanediol (I, 0.81 g; II, 0.87 g) was dissolved in 10 ml of anhydrous pyridine and cooled to 0°. After addition of 10 ml of acetic anhydride the solution was allowed to warm to room temperature. After 17 hr, the solvents were removed at 25° (1 Torr) to yield the crude acetate. This yellow oil was dissolved in 20 ml of glacial acetic acid and ozonized with a stream of approximately 1% ozone in oxygen at a rate of 1.8 l./min (I for 2.75 hr, II for 2.5 hr). Following ozonolysis the solution was diluted with 40 ml of 2% aqueous hydrogen peroxide and heated for 30 min on the steam bath. These solutions were concentrated to ~10 ml at 25° (1

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Torr) and then further concentrated with an air stream overnight.

The oil was dissolved in a little methanol, and ethereal diazomethane (less than 1 g, from Diazald, following the procedure of de Boer)[13] was added until the yellow color remained. After 1 hr at room temperature the solvents were removed *in vacuo*. The crude products were chromatographed on 75 g of SilicAR CC-7 with 7:3 chloroforom–Skellysolve B by the procedure described for the preparation of this compound from methyl methacrylate. Gas chromatography at 190° led to a combination of identical fractions. Crystallization from ether–hexane gave the following physical constants for the two samples of 3-*O*-acetyl-(*R*)-2,3-dihydroxy-2-methylpropanoate. Sample I (derived from (*S*)-atrolactic acid) weighed 0.49 g (52.3%), mp 31–34°. The rotation of sample I (optical purity 77.1%) was determined, $[\alpha]^{23}D$ −7.33° (*c* 6.09, EtOH), from which the rotation of an optically pure sample in ethanol is calculated to be −9.52°.

Anal. Calcd for $C_7H_{12}O_5$: C, 47.72; H, 6.87. Found: C, 48.00; H, 7.01.

Sample II (derived from α-methylstyrene) weighed 0.62 g (61.5%), mp 35–36°C, $[\alpha]^{23}D$ −9.18° (*c* 5.07, EtOH). Assuming that sample II is 97.5% optically pure, the rotation for a pure sample should be −9.42°.

Anal. Calcd for $C_7H_{12}O_5$: C, 47.72; H, 6.87. Found: C, 47.49; H, 6.74.

Registry No.—**1**, 35638-89-2; (*R*)-**1**, 35638-90-5; **2**, 4217-66-7; (*R*)-**2**, 35638-92-7; (*S*)-**2**, 2406-22-6; (*R,S*)-**3**, 35638-93-8; (*S,R*)-**3**, 35638-94-9; (*R*)-**4**, 35638-95-0; (*S*)-**4**, 35638-96-1; **5**, 19860-56-1; **6**, 35638-98-3.

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Mesomorphic Properties of Some Ring-Methylated Phenyl Benzoyloxybenzoates

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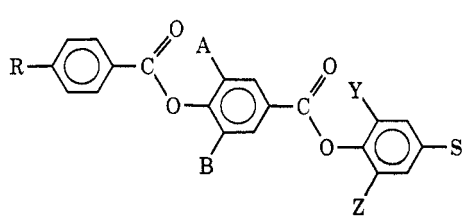
To delineate the role of laterally placed methyl groups upon mesomorphic character, a series of esters of the general formula 1 was prepared, where R and S were ethoxyl and butyl, respectively, and A, B, Y, and Z were the nine independent combinations of methyl and hydrogen. Every derivative exhibited a nematic phase, and the nematic–isotropic transition temperatures decreased as the number of appended methyl groups increased. An investigation of the nematic–isotropic transition by means of differential scanning calorimetry revealed that methylation of the central ring increased the intermolecular interactions and order in the nematic phase, relative to the isotropic phase, while no such effect was apparent upon methylation of the terminal ring. This result demonstrates that the concept of increased intermolecular separation, resulting from laterally placed substituents, is not always sufficient to account for a decrease in nematic–isotropic transition temperatures.

As part of our efforts to obtain stable, low-melting nematic liquids with long mesomorphic ranges and to delineate the effects of symmetry and molecular structure upon mesomorphic properties,[1-3] an investigation was undertaken to uncover the liquid crystalline character of a series of esters derived from phenyl 4-benzoyloxybenzoate.[4] Previous work on more symmetrical esters, *viz.*, the 1,4-phenylene bis(4-*n*-alkoxybenzoates)[5-9] and di-4-*n*-alkoxyphenyl terephthalates,[7] have demonstrated that these esters can exhibit very long nematic ranges (~100°). In addition, Arora, *et al.*, by affixing a methyl group to the central ring of one of their phenylene bisbenzoates, have prepared a material, the lowest melting substance in either series, with a nematic range of 72–156°.[8]

For this investigation, compounds of the general formula **1** were prepared, where R and S were selected to be ethoxyl and *n*-butyl, respectively, in analogy with the low melting points and high nematic CMD values (clearing point/melting point differences[2]) for Schiff bases,[10-12] acetylenes,[13] and chlorostilbenes.[1,2] With the aim of understanding the role of laterally placed methyl groups upon mesomorphic properties, nine compounds were prepared corresponding to all independent combinations of methyl and hydrogen in positions A, B, Y, and Z. Two compounds in which R and S were interchanged were also prepared. The pertinent phase transition temperatures of the compounds were determined, and, in addition, the enthalpies and entropies of the mesomorphic transitions were measured by differential scanning calorimetry. The results are presented in the next section.



1

Results and Discussion

Synthesis.—The esters prepared in this investigation and their physical properties are listed in Tables IA and IB. The sequence of reactions employed in their

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