collected by filtration to afford the *N*-chloro-*N*-sodiocarbamates.

The salts prepared and isolated in this way were dry. The IR spectra of the compounds indicated the absence of water of hydration. The *N*-chloro-*N*-sodiocarbamates are hygroscopic and should be stored in a desiccator in a freezer (ca. −20 °C). When stored in this way at low temperature these reagents were stable for at least 6 months.

General Procedure for the Catalytic Hydroxyamination of Olefins Using *N*-Chloro-*N*-sodiocarbamates and Various Metallic Salts with or without Added Et_4NOAc. A one-necked, round-bottomed flask (25 mL) equipped with a magnetic stirrer was charged with 1.5 mmol of the desired *N*-chloro-sodiocarbamate,[11] the appropriate number of equivalents of a metallic salt (i.e., a stoichiometric amount + 5% excess), and 10 mL of reagent-grade acetonitrile. After the mixture was stirred at room temperature for ~5 min, a milky brown suspension resulted. To this suspension was added 81 μL (4.5 mmol) of water, 1 mmol of olefin, and 0.01 mmol of OsO_4 as a solution in *tert*-butyl alcohol.[3] The mixture was stirred at room temperature for ~5 min and then, if planned, 1 mmol of Et_4NOAc was added; stirring was continued at room temperature until the olefin disappeared from the reaction mixture. In case an excess of metallic salt had been used, the appropriate number of equivalents of saturated sodium chloride solution was added to precipitate the remaining metallic ion [e.g., 0.25 mL (1.5 mmol) if the excess was twice the necessary number of equivalents]. The solid salts were removed by filtration. The filtrate was refluxed for several hours (3–6) with 2 mL of 5% aqueous sodium sulfite. The workup is identical with that described immediately below for the in situ procedure.

In Situ Procedure for the Catalytic Hydroxyamination of Olefins. A one-necked, round-bottomed flask (25 mL) equipped with a magnetic stirrer was placed in an ice bath and charged with a solution of 1.5 mmol of the desired carbamate in 10 mL of reagent-grade acetonitrile. To this ice-cold solution was added 1.7 mL (1.6 g, 1.5 mmol) of *tert*-butyl hypochlorite, and the mixture was stirred for 5 min. Then 1.7 g (0.75 mmol) of silver oxide was added, and stirring was continued for 10 min. To the resulting suspension was added 1 mmol of the olefin, 0.1 mL of an OsO_4 solution in *tert*-butyl alcohol, and 40 μL (2.2 mmol) of water. After 5 min, the ice bath was removed and stirring was continued at room temperature until the olefin had been consumed. Filtration of the reaction mixture gave a solution that was refluxed for several hours (3–6) with 2 mL of 5% aqueous sodium sulfite. The resulting mixture was concentrated in a rotary evaporator, and the largely aqueous residue was extracted with two 10-mL portions of methylene chloride. The organic phase was dried ($MgSO_4$) and concentrated to give the crude hydroxycarbamate. When mixtures were formed, chromatography on silica gel was used to separate the regioisomers. When only one hydroxy carbamate was produced, recrystallization of the crude reaction product was the preferred method of purification.

Acknowledgment. We are grateful to the National Science Foundation (CHE77-14628), Hoffmann-La Roche, and Eli Lilly for financial support.

Registry No. *t*-BuOC(O)NClNa, 73210-14-7; EtOC(O)NClNa, 17510-52-0; $EtOC(O)NH_2$, 51-79-6; $HgCl_2$, 7487-94-7; $Hg(NO_3)_2$, 10045-94-0; $Hg(OAc)_2$, 1600-27-7; $AgNO_3$, 7761-88-8; $Zn(OAc)_2$, 557-34-6; $Cd(OAc)_2$, 543-90-8; $Cd(NO_3)_2$, 10325-94-7; $Cu(OAc)_2$, 142-71-2; $Zn(NO_3)_2$, 7779-88-6; $CdCl_2$, 10108-64-2; $ZnCl_2$, 7646-85-7; Ag_2O, 20667-12-3; styrene, 100-42-5; (*E*)-5-decene, 7433-56-9; (*E*)-stilbene, 103-30-0; 1-methylcyclohexene, 591-49-1; 2-methyl-2-heptene, 627-97-4; 1-phenylcyclohexene, 771-98-2; 3-methyl-2-cyclohexenone, 1193-18-6; *tert*-butyl *threo*-[6-(5-hydroxy)decyl]carbamate, 67341-06-4; ethyl *threo*-[6-(5-hydroxy)decyl]carbamate, 73210-15-8; ethyl *threo*-[1-(2-hydroxy-1,2-diphenyl)ethyl]carbamate, 73197-89-4; *tert*-butyl *threo*-[1-(2-hydroxy-1,2-diphenyl)ethyl]carbamate, 67366-52-3; ethyl *cis*-[1-(2-hydroxy-2-methyl)cyclohexyl]carbamate, 73197-90-7; ethyl [3-(2-hydroxy-2-methyl)heptyl]carbamate, 73197-91-8; ethyl *cis*-[1-(2-hydroxy-2-phenyl)cyclohexyl]carbamate, 73197-92-9; ethyl *cis*-[1-(2-oxo-6-hydroxy-6-methyl)cyclohexyl]carbamate, 73197-93-0; Et_4NOAc, 1185-59-7; OsO_4, 20816-12-0.

(11) Either the crude or the ether-washed *N*-chlorosodiocarbamate can be used. The difference in the isolated yield of hydroxycarbamate is generally small (cf. examples 6 and 7 in Table IV).

Conversion of Carbalkoxymethyl Groups to γ-Oxocrotonate Derivatives

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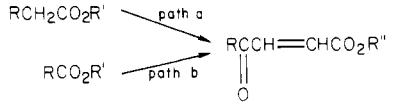
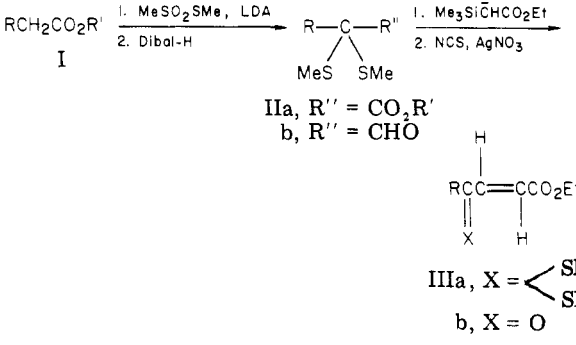
In the course of our ongoing effort directed toward the total synthesis of (±)-brefeldin A,[1] we required an efficient means of transforming a carbalkoxymethyl group to a ketone-protected γ-oxocrotonate unit that ultimately could be deprotected under mild, selective conditions. Surprisingly, there are few published methods[2] for effectively carrying out this overall process (eq 1, path a) in contrast



(1)

with the numerous procedures[3] that are available for converting a carbalkoxyl group to the corresponding γ-oxocrotonate derivative (eq 1, path b). In that γ-oxygenated crotonate derivatives are widespread in nature,[4] an efficient method for accomplishing this complementary conversion undoubtedly would be quite useful.

A sequence of reactions that we have found to be particularly well suited for our brefeldin synthesis and which appears to be generally applicable for effecting the carbalkoxymethyl → γ-oxocrotonate transformation is shown in eq 2. As can be seen from the examples given in Table



(2)

I, the yields on the average are quite high (ca. 85%) at each stage with the exception of the thioketal hydrolysis, for which the yields vary from 55 to 71%.[5] The synthetic advantages afforded by such a protected ketone function, which can be introduced in a single step[6] and hydrolyzed

(1) For our previous work in this area, see: R. Baudouy, P. Crabbé, A. E. Greene, C. Le Drian, and A. F. Orr, *Tetrahedron Lett.*, 2973 (1977).

(2) (a) E. J. Corey, R. H. Wollenberg, and D. R. Williams, *Tetrahedron Lett.*, 2243 (1977); ref 1. (b) See also P. Montellano and C. K. Hsu, *ibid.*, 4215 (1976).

(3) (a) E. J. Corey and R. H. Wollenberg, *Tetrahedron Lett.*, 4705 (1976); (b) P. A. Bartlett, *J. Am. Chem. Soc.*, **98**, 3305 (1976); (c) P. Bakuzis, M. L. F. Bakuzis and T. Weingartner, *ibid.*, **100**, 2371 (1978), and references cited therein.

(4) For examples of γ-oxygenated crotonate natural products, see: K. C. Nicolaou, *Tetrahedron*, **33**, 683 (1977); S. Masamune, *Aldrichimica Acta*, **11**, 23 (1978). See also, footnote 1 in ref 3 b.

(5) (a) E. J. Corey and B. Erickson, *J. Org. Chem.*, **36**, 3553 (1971). For related examples, see: (b) E. W. Colvin, T. A. Purcell, and R. A. Raphael, *J. Chem. Soc., Perkin Trans.*, 1718 (1976); (c) D. Seebach, B. Seuring, H.-O. Kalinowski, W. Lubosch, and B. Renger, *Angew. Chem., Int. Ed. Engl.*, **16**, 264 (1977); (d) K. F. Burri, R. A. Cardone, W. Y. Chen, and P. Rosen, *J. Am. Chem. Soc.*, **101**, 7068 (1979).

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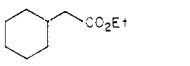
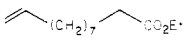
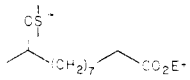
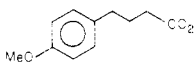
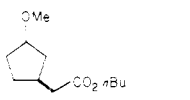
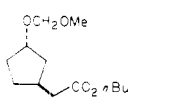
Table I. Conversion of Esters to Oxocrotonate Derivatives

ester I	yield,[a] % IIa	IIb[b]	IIIa	IIIb
	99	97 (83)	92 (84)[c]	69 (67)[d]
	93	79 (70)	92	71 (37)[e]
	64	75 (70)	76	65
	81	86 (81)	90	55
	91	94 (90)	87	56
	80	92 (77)	85[f]	58[f]

[a] Yields are for pure products after chromatography. [b] Yield takes into account the additional quantity of aldehyde which was obtained by Collins oxidation of the small amount of overreduced material. Yield of aldehyde obtained directly from Dibal-H reduction is in parentheses. [c] Yield obtained by using triethyl phosphonoacetate. [d] Yield obtained by using *N*-iodosuccinimide as described in ref 5d. [e] Yield obtained by using $HgO-BF_3 \cdot OEt_2$ as described by E. Vedejs and P. L. Fuchs, *J. Org. Chem.*, **36**, 366 (1971). [f] *tert*-Butyl ester (*tert*-butyl trimethylsilylacetate was used in this case).

selectively, are considerable, however, and in general should more than compensate.

It is interesting that the lithio derivative of ethyl (and *tert*-butyl) (trimethylsilyl)acetate produces almost exclusively the trans isomer (by NMR) in IIb → IIIa in contrast with other applications of this reagent.[7,8] Alternatively, the sodium salt of triethyl phosphonoacetate can be employed, but the reaction in this case is very slow even at 30 °C with an excess of the reagent, and the yield of ester IIIa is somewhat lower.[5b-d]

We expect that this sequence will prove useful for the synthesis of other γ-oxygenated crotonate products due to the generally high yields, stereoselectivity, mild reaction conditions, and the flexible nature of the intermediates.

Experimental Section

Solvents were distilled prior to use: tetrahydrofuran (THF) and dimethoxyethane (DME) from lithium aluminum hydride, diisopropylamine from sodium hydride, and toluene from sodium. Merck 70–230-mesh silica gel 60 was employed for column chromatography. A Beckman Acculab 4 spectrophotometer was used to record IR spectra (neat film), and a JEOL PMX-60 spectrometer was used for the NMR spectra (Me_4Si as the internal reference). Mass spectra and microanalyses were run by the Central Service of the CNRS.

Typical procedures are illustrated by the conversion of ethyl cyclohexylacetate to (*E*)-ethyl 4-cyclohexyl-4-oxo-2-butenoate.

Ethyl 2,2-Bis(methylthio)cyclohexylacetate. Ethyl cyclohexylacetate (0.85 g, 5 mmol) dissolved in 20 mL of dry THF under N_2 at −78 °C was treated with 6 mL (5.5 mmol) of a 0.92 M solution of lithium diisopropylamide (LDA) in THF. After 20 min at −78 °C, 570 μL (6 mmol) of $MeSO_2SMe$[2b,9] was added, and the solution was stirred at room temperature for 20 min. The solution was then cooled to −78 °C, and 7.1 mL (6.5 mmol) of the LDA solution was added. After 20 min at room temperature the solution was once again cooled to −78 °C, treated with 660 μL (7 mmol) of $MeSO_2SMe$, and then allowed to come to room temperature. After 15 min, aqueous NH_4Cl was added, and the reaction mixture was extracted with ether. The ether was dried over $MgSO_4$ and evaporated, and the crude oil was purified by silica gel chromatography, affording 1.30 g (99%) of product: IR λ_{max} 1725, 1450, 1215, 1025 cm^{-1}; NMR (CCl_4) δ 4.1 (q, J = 7 Hz, 2 H), 2.05 (s, 6 H), 1.3 (t, J = 7 Hz, 3 H).

Anal. Calcd for $C_{12}H_{22}S_2O_2$: C, 54.95; H, 8.45. Found: C, 54.76; H, 8.29.

Ethyl 2,2-Bis(methylthio)cyclohexylacetaldehyde. The above ester (685 mg, 2.6 mmol) dissolved in 15 mL of toluene under nitrogen was cooled to −110 °C (liquid nitrogen-ether bath). Diisobutylaluminum hydride in toluene (4 mL, 1.2 M) was added, and the mixture was stirred for 40 min between −90 and −100 °C. Methanol (1 mL) was then added slowly at −100 °C. The mixture was allowed to come to room temperature, and 30 mL of a saturated aqueous solution of NH_4Cl and 100 mL of ether were added. After being stirred for 15 min, the mixture was extracted with ether three times, the ether layer was dried over K_2CO_3 and evaporated, and the product was purified on silica gel, affording 473 mg (83%) of pure aldehyde. The corresponding alcohol (100 mg, impure), eluted in later fractions, was dissolved in 10 mL of dichloromethane and treated at room temperature with 600 mg of Collins reagent. The usual workup and purification provided an additional 82 mg (14%) of aldehyde: IR λ_{max} 2720, 1710, 1450 cm^{-1}; NMR (CCl_4) δ 8.8 (s, 1 H), 1.95 (s, 6 H).

The proportion of alcohol in the mixture was significantly increased when the reduction was run at higher temperatures.

(*E*)-Ethyl 4,4-Bis(methylthio)-4-cyclohexyl-2-butenoate. (A) Via the Emmons–Horner Reaction. Triethyl phosphonoacetate (235 mg, 1.05 mmol) in 1 mL of DME was added to a stirred mixture of sodium hydride [44 mg (1 mmol) of a 55% dispersion in oil] in 5 mL of DME at −78 °C under nitrogen. The mixture was allowed to warm to room temperature and was stirred for 45 min. The aldehyde (165 mg, 0.75 mmol) was then added at −78 °C, and the mixture was stirred overnight at 25 °C. As starting aldehyde remained, an additional 0.5 mmol of the sodio derivative of triethyl phosphonoacetate was added and the mixture was stirred at 30 °C for 20 h. After the addition of 3 drops of glacial acetic acid, the solvent was evaporated, and the resulting oil was diluted with methylene chloride and filtered through silica gel. The crude product was then purified by silica gel chromatography, affording 184 mg (84%) of ester: IR λ_{max} 1720, 1640, 1450, 1370, 1290, 1180, 985, 790 cm^{-1}; NMR (CCl_4) δ 6.1 (AB q, J = 15 Hz, $\delta_a - \delta_b$ = 54 Hz, 2 H), 4.05 (q, J = 7 Hz, 2 H), 1.95 (s, 6 H), 1.3 (t, J = 7 Hz, 3 H).

The corresponding acid (LiOH–EtOH–H_2O, 100%) has a melting point of 138 °C (ether–pentane).

Anal. Calcd for $C_{12}H_{20}O_2S_2$: C, 55.37; H, 7.75. Found: C, 55.30; H, 7.68.

(B) Via the Ethyl (Trimethylsilyl)acetate Method. Ethyl (trimethylsilyl)acetate (800 mg, 5 mmol) dissolved in 15 mL of THF under nitrogen was cooled to −78 °C and treated with 4.6 mL of a THF solution of LDA (0.92 M, 4.2 mmol). After the mixture was stirred for 15 min at −78 °C, 751 mg (3.4 mmol) of the above aldehyde was added, and the reaction was left overnight at −35 °C. It was then allowed to come to room temperature and was quenched with aqueous NH_4Cl, and the product was isolated

(6) Cf.: P. G. Gassman and R. J. Balchunis, *J. Org. Chem.*, **42**, 3236 (1977); Y. Nagao, K. Kaneko, K. Kawabata, and E. Fujita, *Tetrahedron Lett.*, 5021 (1978). The diphenyl thioketal corresponding to the cyclohexyl derivative IIIa could also be synthesized in comparable yield; however, we were unable to effect in a single operation a satisfactory hydrolysis of this compound [cf.: B. M. Trost, T. N. Salzmann and K. Hiroi, *J. Am. Chem. Soc.*, **98**, 4887 (1976); B. M. Trost and G. S. Massiot, *ibid.*, **99**, 4405 (1977)].

(7) In any event, *cis*-γ-oxocrotonates are known[3b] to isomerize rapidly to the more stable trans derivatives IIIb.

(8) K. Shimoji, H. Taguchi, K. Oshima, H. Yomamoto, and H. Nazaki, *J. Am. Chem. Soc.*, **96**, 1620 (1974); S. O. Hartzell, D. F. Sullivan, and M. W. Rathke, *Tetrahedron Lett.*, 1463 (1974); P. A. Grieco, C.-L. J. Wang, and S. D. Burke, *J. Chem. Soc., Chem. Commun.*, 537 (1975).

(9) H. J. Backer, *Bull. Soc. Chim. Belg.*, **62**, 3 (1953); *Chem. Abstr.*, **48**, 5075c (1954). This is also available from Aldrich. Methyl methanethiosulfonate (and the reaction products) has little odor, which makes it considerably more agreeable to work with than dimethyl disulfide.

with ether. Purification on silica gel gave 916 mg (92%) of ester: IR as above; NMR as above but also displaying minor resonances at 6.2, 5.8, and 5.55 ppm.

Anal. Calcd for $C_{14}H_{24}O_2S_2$: C, 58.31; H, 8.39. Found: C, 58.20; H, 8.43.

(*E*)-Ethyl 4-Cyclohexyl-4-oxo-2-butenoate. A solution of 232 mg (0.81 mmol) of the above thioketal in 3 mL of CH_3CN was added to 430 mg (3.22 mmol) of *N*-chlorosuccinimide and 617 mg (3.62 mmol) of silver nitrate dissolved in 15 mL of CH_3CN–H_2O (8:2) at −15 °C. The resulting mixture was stirred for 15 min at −15 °C and then treated with 3 mL of 10% aqueous sodium sulfite. The mixture was poured into brine, and the product was isolated with ether. Chromatography of the crude product on silica gel afforded 110 mg (69%) of the desired enone ester: IR λ_{max} 3015, 1725, 1700, 1640, 1450, 1370, 1305, 1280, 1180, 1030, 980 cm^{-1}; NMR (CCl_4) δ 6.77 (AB q, J = 15 Hz, $\delta_a - \delta_b$ = 28 Hz, 2 H), 4. 13 (q, J = 7 Hz, 2 H), 2.4 (m, 1 H), 1.28 (t, J = 7 Hz, 3 H).

Anal. Calcd for $C_{12}H_{18}O_3$: C, 68.54; H, 8,63; mol wt 210.1255. Found: C, 68.58; H, 8.67; mol wt (mass spectrum) 210.1267.

(*E*)-Ethyl 4-oxo-2,12-tridecadienoate: IR λ_{max} 3090, 3005, 1730, 1705, 1640, 1590, 1310, 1190, 1040, 990, 915 cm^{-1}; NMR (CCl_4) δ 6.57 (AB q, J = 15 Hz, $\delta_a - \delta_b$ = 24 Hz, 2 H), 5.6 (br m, 1 H), 4.8 (m, 2 H), 4.1 (q, J = 7 Hz, 2 H), 2.5 (br t, 2 H), 1.9 (m, 2 H), 1.3 (t, J = 7 Hz, 3 H), 1.3 (br s, 10 H).

Anal. Calcd for $C_{15}H_{24}O_3$: C, 71.39; H, 9.59; mol wt 252.1725. Found: C, 71.56; H, 9.62; mol wt (mass spectrum) 252.1738.

(*E*)-Ethyl 12-[(*tert*-butyldimethylsilyl)oxy]-4-oxo-2-tridecenoate: IR λ_{max} 1730, 1700, 1640, 1460, 1370, 1300, 1260, 1100, 1040, 840, 780 cm^{-1}; NMR (CCl_4) δ 6.55 (AB q, J = 15 Hz, $\delta_a - \delta_b$ = 22 Hz, 2 H), 4.1 (q, J = 7 Hz, 2 H), 3.65 (m, 1 H), 2.5 (br t, 2 H), 1.3 (t, J = 7 Hz, 3 H), 1.3 (br s, 12 H), 1.08 (d, J = 6 Hz, 3 H), 0.70 (s, 9 H).

Anal. Calcd for $C_{21}H_{40}O_4Si$: C, 65.58; H, 10.48. Found: C, 65.70; H, 10.52.

(*E*)-Ethyl 6-(*p*-methoxyphenyl)-4-oxo-2-hexenoate: IR λ_{max} 3060, 3020, 1720, 1700, 1630, 1610, 1580, 1510, 1300, 1250, 1180, 1030, 980, 820 cm^{-1}; NMR (CCl_4) δ 6.6 (m, 6 H), 4.1 (t, J = 7 Hz, 2 H), 3.65 (s, 3 H), 2.8 (s, m in CD_3COCD_3, 4 H), 1.3 (t, J = 7 Hz, 3 H).

Anal. Calcd for $C_{15}H_{18}O_4$: mol wt 262.1204. Found: mol wt (mass spectrum) 262.1214.

(*E*)-Ethyl 4-[(1α,3β)-3-methoxycyclopentyl]-4-oxo-2-butenoate: IR λ_{max} 3060, 1720, 1700, 1640, 1590, 1460, 1370, 1305, 1280, 1180, 1090, 1030, 980 cm^{-1}; NMR (CCl_4) δ 6.66 (AB q, J = 15 Hz, $\delta_a - \delta_b$ = 25 Hz, 2 H), 4.1 (t, J = 7 Hz, 2 H), 3.7 (m, 1 H), 3.25 (m, 1 H), 3.15 (s, 3 H), 1.3 (t, J = 7 Hz, 3 H).

Anal. Calcd for $C_{12}H_{18}O_4$: mol wt 226.1204. Found: mol wt (mass spectrum) 226.1203.

(*E*)-*tert*-Butyl 4-[(1α,3β)-3-methoxymethoxycyclopentyl]-4-oxo-2-butenoate: IR λ_{max} 1720, 1700, 1635, 1460, 1370, 1310, 1150, 1040, 980, 920, 850 cm^{-1}; NMR (CCl_4) δ 6.6 (AB q, J = 15 Hz, $\delta_a - \delta_b$ = 22 Hz, 2 H), 4.4 (s, 2 H), 4.05 (m, 1 H), 3.3 (m, 1 H), 3.2 (s, 3 H), 1.5 (s, 9 H).

Registry No. I (R = cyclohexyl, R′ = Et), 5452-75-5; I (R = $(CH_2)_7CH{=}CH_2$, R′ = Et), 692-86-4; I (R = $(CH_2)_7CHMe(OSiMe_2Bu\text{-}t)$, R′ = Et), 73434-17-0; I (R = $CH_2CH_2C_6H_4$-*p*-OMe, R′ = Et), 4586-89-4; I (R = *trans*-3-MeO-cyclopentyl, R′ = Bu), 73434-18-1; I (R = *trans*-3-$MeOCH_2O$-cyclopentyl, R′ = Et), 73453-14-2; IIa (R = cyclohexyl, R′ = Et), 73434-19-2; IIa (R = $(CH_2)_7CH{=}CH_2$, R′ = Et), 73434-20-5; IIa (R = $(CH_2)_7CHMe(OSiMe_2Bu\text{-}t)$, R′ = Et), 73434-21-6; IIa (R = $CH_2CH_2C_6H_4$-*p*-OMe, R′ = Et), 73434-22-7; IIa (R = *trans*-3-MeO-cyclopentyl, R′ = Bu), 73434-23-8; IIa (R = *trans*-3-$MeOCH_2O$-cyclopentyl, R′ = Bu), 73434-24-9; IIb (R = cyclohexyl), 73434-25-0; IIb (R = $(CH_2)_7CH{=}CH_2$), 73434-26-1; IIb (R = $(CH_2)_7CHMe(OSiMe_2Bu\text{-}t)$), 73434-27-2; IIb (R = $CH_2CH_2C_6H_4$-*p*-OMe), 73434-28-3; IIb (R = *trans*-3-MeO-cyclopentyl), 73434-29-4; IIb (R = *trans*-3-$MeOCH_2O$-cyclopentyl), 73434-30-7; IIIa (R = cyclohexyl), 73434-31-8; IIIa (R = cyclohexyl), free acid, 73434-32-9; IIIa (R = $(CH_2)_7CH{=}CH_2$), 73434-33-0; IIIa (R = $(CH_2)_7CHMe(OSiMeBu\text{-}t)$), 73434-34-1; IIIa (R = $CH_2CH_2C_6H_4$-*p*-OMe), 73434-35-2; IIIa (R = *trans*-3-MeO-cyclopentyl), 73434-36-3; IIIa (R = *trans*-3-$MeOCH_2O$-cyclopentyl), butyl ester, 73434-37-4; IIIb (R = cyclohexyl), 73434-38-5; IIIb (R = $(CH_2)_7CH{=}CH_2$), 73434-39-6; IIIb (R = $(CH_2)_7CHMe(OSiMe_2Bu\text{-}t)$), 73453-15-3; IIIb (R = $CH_2CH_2C_6H_4$-*p*-OMe), 73434-40-9; IIIb (R = *trans*-3-MeO-cyclopentyl), 73434-41-0; IIIb (R = *trans*-3-$MeOCH_2O$-cyclopentyl), butyl ester, 73434-42-1; $MeSO_2SMe$, 2949-92-0; β,β-bis(methylthio)cyclohexaneethanol, 73434-43-2; triethyl sodiophosphonoacetate, 22822-85-1; ethyl (trimethylsilyl)acetate, 4071-88-9.

Oligonucleotide Analogues with Internucleoside Phosphite Links[1]

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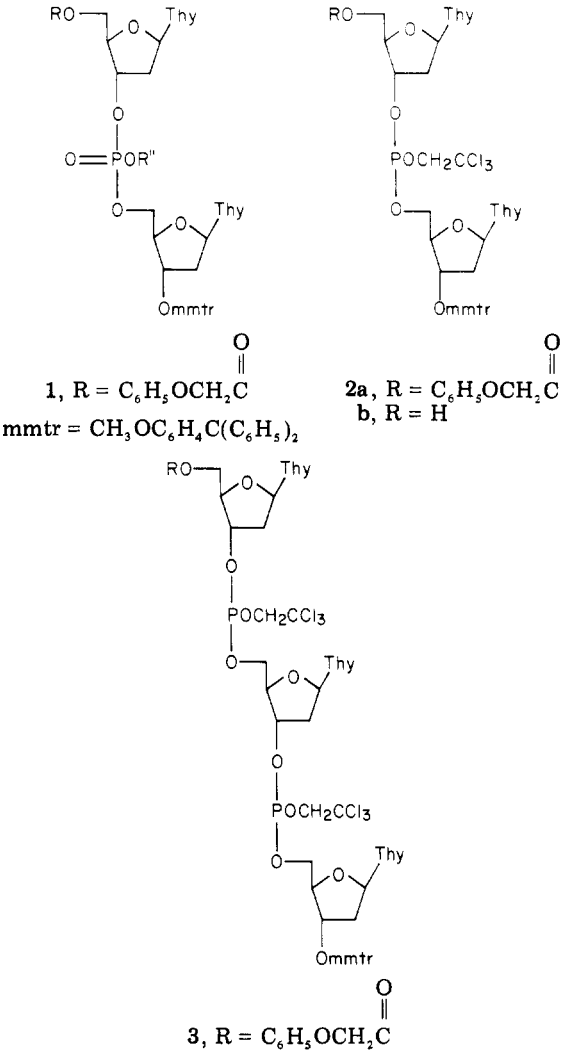
Oligonucleotide derivatives possessing internucleoside phospho triester links (e.g., as in compound 1) have proven



useful in the synthesis of polynucleotides[2] and, in addition, exhibit interesting biochemical properties in their own right.[3] We describe in this note two examples of another class of electrically uncharged oligonucleotide analogues, compounds **2** and **3**, in which nucleosides are joined by phosphite links. Although such compounds are presumed

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(2) For a current review see M. Ikehara, E. Ohtsuka, and A. F. Markham, *Adv. Carbohydr. Chem. Biochem.*, **36**, 135–213 (1979).

(3) J. C. Barrett, P. S. Miller, and P. O. P. Ts'o, *Biochemistry*, **13**, 4897–4906 (1974); R. C. Pless and P. O. P. Ts'o, *ibid.*, **16**, 1239–1250 (1977).

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