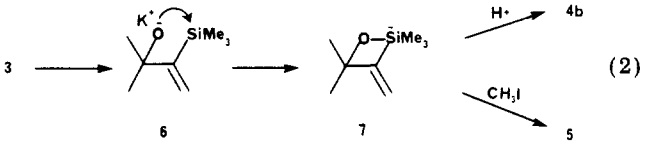
3 was treated with KH/THF, rapid migration[9] of the trimethylsilyl group from carbon to oxygen resulted with the formation of **4b**. The same reaction proceeded with HMPA as the solvent to form **4b** within 1 min at 0 °C. Isolation of product resulted in loss of trimethylsilyl to yield **4a**. If the reaction mixture is quenched with D_2O, no deuterium incorporation is observed at the vinyl carbon, but if the reaction is allowed to proceed *in the presence* of excess CH_3I, methyl ether **5** is formed.

We suggest the following mechanism:[6,7] deprotonation of 3 (eq 2) leads to highly basic alkoxide **6**, which may exist



(2)

as the pentavalent silicon anion **7**. Alkylation on oxygen or protonation on carbon leads to the observed products. In conclusion, the evidence[8] suggests that the Brook rearrangement may be more general than originally proposed.[9]

Experimental Section

Preparation of Compound 3. To a solution of 1 g (5.59 mmol) of α-bromovinyltrimethylsilane in 20 mL of dry ether at −78 °C was added 1.5 equiv of *tert*-butyllithium (Alfa). The mixture was warmed to −20 °C for 2 h, and then 825 mg (5.5 mmol) of 2-adamantanone in 10 mL of ether was added. After 1 h, the reaction was warmed to room temperature and worked up in the usual way to product 1.3 g of white crystals, mp 76–79 °C (95%). Recrystallization gave 923 mg, mp 84–85 °C (67%): TLC (silica gel, 5% ether/pentane) R_f 0.37; NMR (CCl_4) δ 4.5 (2 H, dd) 1.0–2.2 (14 H, m), 0.0 (9 H, s); IR (CCl_4) 3600 cm^{-1}; MS, *m/e* (relative intensity) 250 (1), 236 (27), 235 (90), 161 (36), 160 (100), 151 (85), 150 (78), 127 (19); calcd for $C_{15}H_{26}OSi$ 250.17529, found 250.17314.

Isomerization of Compound 3. A. A solution of 76 mg (0.3 mmol) of compound 3 in 0.5 mL of THF and 2 mL of HMPA was cooled to 0 °C and treated with a slight excess of KH (22% dispersion in oil). After 1 min, analysis (aliquot worked up with pentane/H_2O) revealed no starting material remaining, and GC, GC/MS, and TLC indicated mostly **4b** present. Usual workup (ether/H_2O) gave an oil, which was purified by preparative TLC to yield 20 mg of white crystals of **4a** (37%).[10] Compound **4a** possessed spectral and analytical properties identical with those of an authentic sample prepared by the addition of vinylmagnesium bromide to 2-adamantanone: TLC (5% ether/pentane) R_f 0.05; NMR δ 6.0–6.5 (m, 1 H), 4.9–5.4 (m, 2 H), 1.4–2.4 (m, 14 H), 1.1 (s, 1 H); IR (CCl_4) 3600 cm^{-1}.

B. A solution of 111 mg (0.44 mmol) of compound 3 in 5 mL of dry THF under argon was treated with a slight excess of KH (ca. 20% dispersion in oil, Alfa). The mixture was stirred at 0 °C for 5 min and then at room temperature for 1 h. Usual workup (ether/H_2O) gave an oil, which was purified by preparative TLC to yield 69 mg (63%) of compound **4b**: TLC (5% ether, pentane) R_f 0.57; NMR δ 5.6–6.1 (m, 1 H), 5.0–5.4 (m, 2 H), 1.2–2.4 (m, 14 H), 0.0 (s, 9 H); IR, no OH; MS, *m/e* (relative intensity) 250 (100), 235 (61), 181 (23), 161 (53), 91 (26), 79 (27), 75 (69), 73 (96); calcd for $C_{15}H_{26}OSi$ 250.17529, found 250.17438.

If the reaction mixture in method A or B was quenched with D_2O, no deuterium incorporation at the vinyl position was observed.

Alkylation of Anion 6. Alcohol 3 (76 mg, 0.3 mmol), a few (excess) milliliters of CH_3I (filtered through silica gel), and 5 mL of dry THF were cooled to 0 °C, and a slight excess of KH was added. After 10 min, GC analysis showed the disappearance of starting material. Usual workup gave 55 mg (73%) of compound **5** after preparative TLC: TLC (5% ether/pentane) R_f 0.62; NMR δ 5.6–5.7 (m, 2 H), 2.78 (s, 3 H), 1.1–2.3 (m, 14 H), 0.0 (s, 9 H); IR, no OH; MS, *m/e* (relative intensity) 251 (44), 250 (95), 235 (70), 207 (21), 193 (25), 181 (42), 168 (24), 165 (78), 161 (68), 160 (21), 119 (23), 117 (27), 105 (30), 91 (51), 89 (22), 81 (22), 79 (51), 77 (23), 75 (80), 73 (100), 67 (24); calcd for $C_{16}H_{28}OSi$ 264.19095, found 264.19073.

Registry No. 3, 66374-49-0; **4a**, 63563-16-6; **4b**, 87174-36-5; **5**, 87174-37-6; (α-bromovinyl)trimethylsilane, 13683-41-5; 2-adamantanone, 700-58-3.

(6) This type of reaction was first recognized by Hudrlik: (a) Hudrlik, P. F.; Schwartz, R. H.; Kulkarni, A. K. *Tetrahedron Lett.* **1979**, 2233–2236. (b) Hudrlik, P. F.; Nagendrappa, G.; Kulkarni, A. K. *Ibid.* **1979**, 2237–2240.

(7) Several examples of desilylation of β-hydroxy silanes using fluoride ion have been reported: (a) Chan, T. H.; Mychajkowski, W. *Tetrahedron Lett.* **1974**, 3479–3482. (b) Snider, B. B.; Karras, M.; Conn, R. S. E. *J. Am. Chem. Soc.* **1978**, *100*, 4624–4626. (c) Snider, B. B.; Conn, R. S. E.; Karras, M. *Tetrahedron Lett.* **1979**, *1679*–1682. (d) Fristad, W. E.; Bailey, T. R.; Paquette, L. A. *J. Org. Chem.* **1980**, *45*, 3028–3037. (e) Magnus, P.; Roy, G. *J. Chem. Soc., Chem. Commun.* **1979**, 822–823. (f) Magnus, P.; Roy, G. *Organometallics* **1982**, *1*, 553–559.

(8) A recent paper by Hudrlik reports other examples of the "Homo-Brook" rearrangement: Hudrlik, P. F.; Hudrlik, A. M.; Kulkarni, A. K. *J. Am. Chem. Soc.* **1982**, *104*, 6809–6811.

(9) Brook, A. G. *Acc. Chem. Res.* **1974**, *7*, 77–84.

(10) GC showed much of the silyl ether **4b** to be hydrolyzed *during workup* when HMPA was present. A small amount of **4b** was recovered from the preparative TLC of this experiment.

Dioxygenation and Reduction of 2′,3′-Unsaturated *C*-Nucleosides

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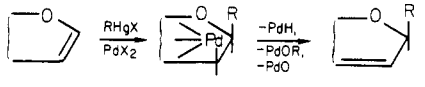
A large number of 2′,3′-unsaturated *N*-nucleosides[1] are synthetically available.[2] The regio- and stereospecific palladium-mediated reaction or organomercuric salts with furanoid or pyranoid glycals gives access also to a variety of 2′,3′-unsaturated *C*-nucleosides.[3,4] As part of a current exploration of the utility of these products as synthetic intermediates, we have dihydroxylated and reduced a few selected compounds with results that are noteworthy.



Catalytic cis dihydroxylation of 1[3e] (Scheme I) using osmium tetroxide and trimethylamine *N*-oxide[5] produced a mixture of two isomeric diols that could not be separated chromatographically. This mixture was treated with 2,2-dimethoxypropane in the presence of *p*-toluenesulfonic acid to afford the corresponding acetonide mixture (2 and 3), which was more amenable to chromatographic sepa-

(1) For convenience, we use the common carbohydrate numbering system (the anomeric carbon is designated 1′) in the running text. Correct nomenclature can be found in the Experimental Section.

(2) (a) Horwitz, J. P.; Chua, J.; DaRooge, M. A.; Noel, M.; Klundt, I. *J. Org. Chem.* **1966**, *31*, 205. (b) Horwitz, J. P.; Chua, J.; Noel, M.; Donnatti, J. T. *Ibid.* **1967**, *33*, 817. (c) Jain, T. C.; Kenkins, I. D.; Russel, A. F.; Verheyden, J. P. H.; Moffat, J. G. *Ibid.* **1974**, *39*, 30. (d) Robins, M. J.; Jones, R. A.; Mengel, R. *J. Am. Chem. Soc.* **1976**, *98*, 8213. (e) Mengel, R.; Serfert, J.-M. *Tetrahedron Lett.* **1977**, 4203. (f) Adachi, T.; Iwasaki, T.; Inoue, I.; Miyoshi, M. *J. Org. Chem.* **1979**, *44*, 1404. (g) Classon, B.; Garegg, P. J.; Samuelsson, B. *Acta Chem. Scand., Ser. B* **1982**, *36*, 251.

(3) (a) Arai, I.; Daves, G. D., Jr. *J. Am. Chem. Soc.* **1978**, *100*, 287; (b) *J. Org. Chem.* **1978**, *43*, 4110; (c) *J. Am. Chem. Soc.* **1981**, *103*, 7683. (d) Arai, I.; Lee, T. D.; Hanna, R.; Daves, G. D., Jr. *Organometallics* **1982**, *1*, 742. (e) Lee, T. D.; Daves, G. D., Jr. *J. Org. Chem.* **1983**, *48*, 399. (f) Hacksell, U.; Daves, G. D., Jr. *Ibid.* 2870.

(4) The formation of 2′,3′-didehydro-2′,3′-dideoxy-1-methyl-5′-*O*-trityl-β-pseudouridine was recently reported as a byproduct in the synthesis of 2-deoxy-*C*-nucleosides: Matsuda, A.; Chu, C. K.; Reichman, U.; Pankiewicz, K.; Watanabe, K. A.; Fox, J. J. *J. Org. Chem.* **1981**, *46*, 3603.

(5) (a) Ray, R.; Matteson, D. S. *Tetrahedron Lett.* **1980**, *21*, *449*. (b) Hauser, F. M.; Prasanna, S. *J. Am. Chem. Soc.* **1981**, *103*, 6378.

0022-3263/83/1948-4144$01.50/0

Table I. ^1H and ^{13}C NMR Chemical Shifts[a] of the Isopropylidene Methyl Groups of 2',3'-Dioxygenated C-Nucleosides Used for Assignments of Anomeric Configurations[b]

	^1H NMR		^{13}C NMR[c]	
cmpd	δ CH_3	Δδ	δ CH_3	Δδ
2	1.35	0.19	24.95	1.79
	1.54		26.74	
3	1.30	0.12	24.95	1.05
	1.42		26.00	
5	1.29	0.10	24.78	1.49
	1.39		26.27	
6	1.33	0.18	24.83	1.52
	1.51		26.35	
8	1.36	0.22	25.14	1.62
	1.58		26.76	
10	1.42	0.26	25.10	1.90
	1.68		27.00	

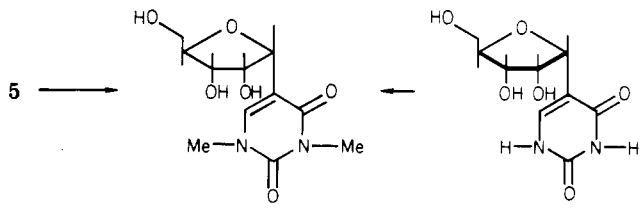
[a] Recorded in $CDCl_3$. [b] Compare ref 7. [c] Absorptions due to N_3 and isopropylidene methyl groups were assigned on the basis of the one-bond carbon-hydrogen coupling constants; $^1J(C,H)$ for the N_3 methyl is around 142 Hz whereas $^1J(C,H)$ for the isopropylidene methyl is around 126 Hz.

ration. Similarly, chiral C-nucleoside 4[3f] was converted to a mixture of 5 and 6 in good yield (Scheme I).

The formation of a 1:1 mixture of 2 and 3 and a 4:1 mixture of 5 and 6 is surprising since cis hydroxylation of alkenes by osmium tetroxide usually occurs on the least sterically hindered face of the double bond.[6] To determine whether the observed stereochemical results indeed are abnormal for 2,5-dihydrofuran derivatives, we subjected compounds 7[3e] and 9[3e] to the dihydroxylaton procedure. In each reaction a single isomer was formed (7 → 8, 9 → 10, Scheme I). Thus, the 1'-pyrimidinyl substituent seems to direct the stereochemistry of osmate ester formation, thereby partially counteracting otherwise dominant steric effects.

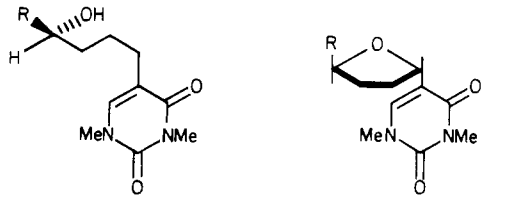
Relative configurations of the acetonide-protected C-nucleosides were determined by using well-documented empirical rules that correlate chemical shifts of the isopropylidene unit in ^1H and ^{13}C NMR spectra with the α or β configuration of nucleosides related to 2,3-O-isopropylidene-D-ribofuranose (see Table I). The chemical shift difference between the isopropylidene methyls is consistently larger for β-nucleosides in which the isopropylidene group is trans to the aglycone than for α-nucleosides in which it is cis.[7] The present correlations demonstrate that this stereorelationship of the isopropylidene group and the aglycone is responsible for the observed effects. The absolute configuration of 5 (and thus indirectly that of 6) was unambigously established by chemical correlation. Deprotection of 5 gave 11, which was identical with an authentic sample prepared from α-pseudouridine (12) by using N,N-dimethylformamide dimethyl acetal according to Hirota et al.[8]

Catalytic hydrogenation of 1 and 4 using palladium (10%) on carbon in methanol resulted in the desired reduction of the 2',3'-double bond but also in hydrogenolysis of the allylic carbon–oxygen bond (1 → 13, 4 → 14).



11 12

However, use of tetrahydrofuran rather than methanol as solvent gave selectively reduced C-nucleosides 15 and 16 in good yields.



13, R = H
14, R = $CH_2OCH_2OCH_3$
15, R = H
16, R = $CH_2OCH_2OCH_3$

Experimental Section

General Comments. Chemicals were used as recieved, except for tetrahydrofuran, which was distilled from litihium aluminum hydride under nitrogen. α-Pseudouridine was purchased from Sigma. Thin-layer chromatography (TLC) was carried out on prescored silica gel GF plates (Analtech). Preparative TLC was carried out on 1-mm thick, 20 × 20 cm, silica gel GF plates (Analtech). For flash chromatography, silica gel 60 (230–400 mesh ASTM, E. Merck) was used. Columns were eluted by using a positive nitrogen pressure. NMR spectra were obtained on a JEOL FX 90Q spectrometer and were referenced to tetramethylsilane. Mass spectra were obtained with a Finnegan 4023 GC/MS/DS system operating at 70 eV using a direct insertion probe. High-resolution mass spectrometry was carried out by Dr. Timothy Wachs, Department of Chemistry, Baker Laboratory, Cornell University, Ithaca, NY. Elemental analyses were carried out by Dr. C. Robertson, Florham Park, NJ.

1,3-Dimethyl-5-[(3aα,4α,6aα)-tetrahydro-2',2'-dimethylfuro[3,4-*d*]-1',3'-dioxol-4-yl]-2,4(1*H*,3*H*)-pyrimidinedione (2) and 1,3-Dimethyl-5-[(3aα,4β,6aα)-tetrahydro-2',2'-dimethylfuro[3,4-*d*]-1',3'-dioxol-4-yl]-2,4(1*H*,3*H*)-pyrimidinedione (3). To an ice-cooled solution of 5-(2',5'-dihydro-2'-furanyl)-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (1)[3e] (620 mg, 2.98 mmol) in acetone (25 mL) were added 2 mL of a 0.05 M solution of osmium tetroxide in *tert*-butyl alcohol and, after 5 min, trimethylamine *N*-oxide dihydrate (333 mg, 3.00 mmol). The reaction mixture was stirred overnight at room temperature and then filtered. Evaporation of volatiles in vacuo afforded a white solid mass to which were added acetone (50 mL), 2,2-dimethoxypropane (4 mL) and *p*-toluenesulfonic acid (7 mg). After the resulting solution was stirred for 5 h at room temperature, excess sodium bicarbonate was added. Filtraton followed by evaporaton of volatiles in vacuo gave a 1:1 mixture of 2 and 3 (according to NMR analysis). Flash chromatography using ether as eluant afforded 97 mg of pure 3, 492 mg of mixed fractons, and 120 mg of 2 (isomeric purity ≥92%). Total yield, 809 mg (96%). Rechromatography of part of the mixed fractons (200 mg) using ether as eluant gave 45 mg of 3, 86 mg of mixed fractions, and 46 mg of 2. Complete separation of a 1:1 mixture of 2 and 3 (50 mg) was obtained by using preparative TLC with ether as eluant.

2: mp 148–150 °C; R_f 0.44 (ether); ^1H NMR ($CDCl_3$) δ 7.22 (d, J = 0.9 Hz, H_6), 4.92 (m, 2 H), 4.77 (m, 1 H), 4.05 (m, $H_{4'}$, $H_{4''}$); 3.42, 3.33 (s's, NMe's); ^{13}C NMR ($CDCl_3$) δ 162.55 (C_4), 151.55 C_2), 141.04 (C_6), 112.66 (C_5), 110.92 ($C(Me)_2$), 84.73, 83.10, 81.70 ($C_{1'}$, $C_{2'}$, $C_{3'}$), 74.27 ($C_{4'}$), 37,06 (N_1 Me), 27.75 (N_3 Me); 26.74, 24.95 (Me's). Anal. Calcd for $C_{13}H_{18}N_2O_5$; C, 55.3; H, 6.42; N, 9.92. Found: C, 55.1; H, 6.33; N, 9.66.

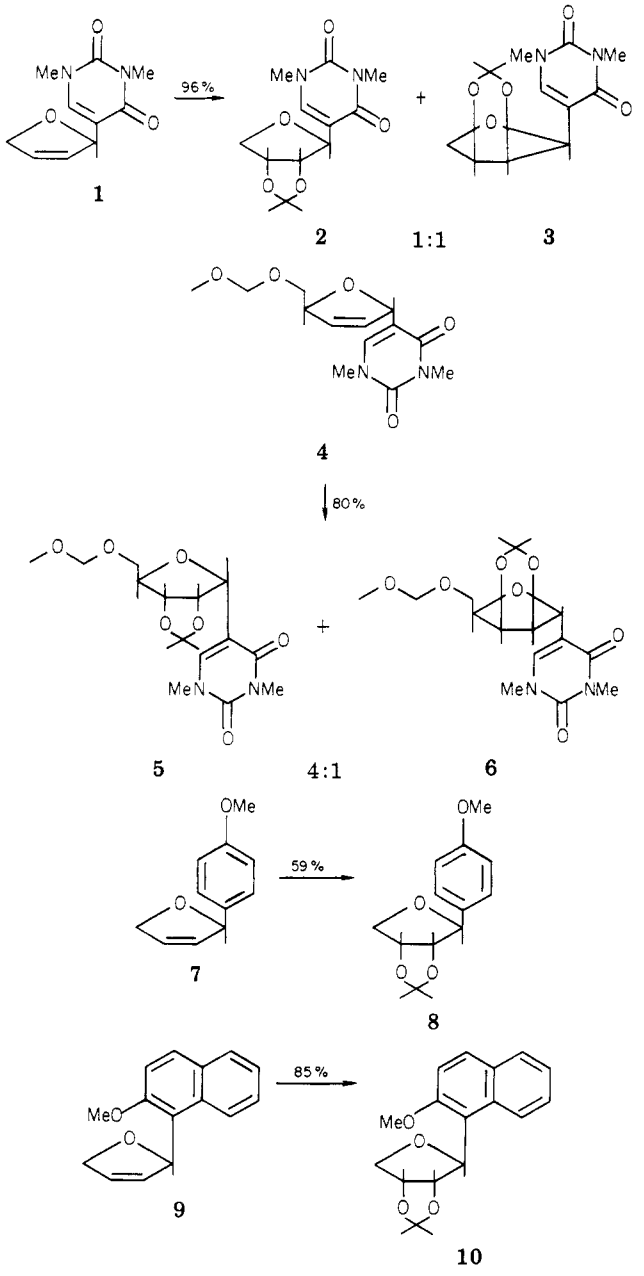
3: mp 185–186 °C; R_f 0.50 (ether); ^1H NMR ($CDCl_3$) δ 7.32 (d, J = 1.1 Hz, H_6), 4.87 (m, 2 H), 4.52 (m, 1 H), 4.19–3.41 (ABm, $H_{4'}$, $H_{4''}$), 3.42, 3.35 (s's, NMe's), 1.42, 1.30 (s's, Me's); ^{13}C NMR

(6) For a review on osmium tetroxide catalyzed cis hydroxylation, see: Schröder, M. *Chem. Rev.* **1980**, *80*, 187. For a recent mechanistic discussion, see: Schröder, M.; Constable, E. S. *J. Chem. Soc., Chem. Commun.* **1982**, 734.

(7) See, e.g.: (a) Imbach, J. L. *Ann. N.Y. Acad. Sci.* **1975**, *255*, 177. (b) Ohrui, H.; Jones, G. H.; Moffat, J. G., Maddox, M. L.; Christensen, A. T.; Bryam, S. K. *J. Am. Chem. Soc.* **1975**, *97*, 4602. (c) Cousineau, T. J.; Secrist, J. A., III, *J. Org. Chem.* **1979**, *24*, 4351.

(8) (a) Hirota, K.; Watanabe, K. A.; Fox, J. J. *J. Org. Chem.* **1978**, *43*, 1193. (b) Hirota, K.; Watanabe, K. A.; Fox, J. J. *J. Heterocycl. Chem.* **1977**, *14*, 537.

Scheme I



(CDCl$_3$) δ 162.14 (C_4), 151.63 (C_2), 140.98 (C_6), 112.01 (C_5), 108.43 (C(Me)$_2$), 81.05, 79.96, 77.63 ($C_{1'}$–$C_{3'}$), 72.30 ($C_{4'}$), 37.14 (N_1 Me), 27.82 (N_3 Me), 26.00, 24.95 (Me's). Anal. Calcd for $C_{13}H_{18}N_2O_5$; C, 55.3; H, 6.42; N, 9.92. Found: C, 55.3; H, 6.48; N, 9.64.

5-[5′-*O*-(Methoxymethyl)-2′,3′-*O*-(1-methylethylidene)-α-D-ribofuranosyl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (5) and 5-[5′-*O*-(Methoxymethyl)-2′,3′-*O*-(1-methylethylidene)-α-D-lyxofuranosyl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (6). A mixture of (2′*S*)-*trans*-5-[2′,5′-dihydro-5′-[(methoxymethoxy)methyl]-2′-furanyl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (**4**,[3f] 297 mg, 1.05 mmol), trimethylamine *N*-oxide (117 mg, 1.05 mmol), acetone (25 mL), and osmium tetroxide in *tert*-butyl alcohol (2 mL) was prepared by using the procedure described for the preparaton of **2** and **3**. After 24 h, ^{1}H NMR of an aliquot indicated the presence of two isomeric diols in an 8:2 ratio (these isomers did not separate on analytical TLC using a variety of solvent systems). The volatiles were evaporated and the residue was dissolved in acetone (25 mL). 2,2-Dimethoxypropane (1 mL) and *p*-toluenesulfonic acid (15 mg) were added, and the resulting solution was stirred overnight. The volatiles were evaporated in vacuo, and the residue was chromatographed on a short silica column with ether as eluant to afford 298 mg (80%) of a 8:2 mixture of **5** and **6**. Separation of the two isomers was effected by using preparative TLC (ether or ethyl acetate).

5: R_f 0.56 (ethyl acetate); mp 112–113 °C; ^{1}H NMR (CDCl$_3$) δ 7.29 (d, J = 1.1 Hz, H_6), 5.14–4.65 (m, 3 H), 4.61 (s, OCH_2O), 4.86–4.70 (m, 1 H), 3.74–3.65 (m, $H_{5'}$, $H_{5''}$), 3.39, 3.34, 3.33 (s's, NMe's, OMe), 1.39, 1.29 (s's, Me's); ^{13}C NMR (CDCl$_3$) δ 162.14 (C_4), 151.61 (C_2), 140.60 (C_6), 112.38 (C_5), 109.06 (C(Me)$_2$), 96.58 (OCH_2O), 82.97, 82.50, 80.85, 77.11 ($C_{1'}$–$C_{4'}$), 67.76 ($C_{5'}$), 55.39 (OMe), 37.08 (N_1 Me), 27.78 (N_3 Me), 26.27, 24.78 (Me's); mass spectrum, m/z (relative intensity) 357 (0.5, MH$^+$), 341 (0.7, M$^+$·–CH$_3$), 45 (100, $CH_3OCH_2^+$); calcd for $C_{16}H_{24}N_2O_7$ + H, 357.1662, found, 357.1634. Anal. Calcd for $C_{16}H_{24}N_2O_7$: C, 53.9; H, 6.79; N, 7.86. Found: C, 53.4; H, 6.68; N, 7.43.

6: R_f 0.48 (ethyl acetate), isomeric purity ≥83%; ^{1}H NMR (CDCl$_3$) δ 7.15 (d, J = 0.9 Hz, H_6), 5.00–4.60 (m, 3 H), 4.68 (s, OCH_2O), 4.45–4.35 (m, 1 H), 4.00–3.65 (m, $H_{5'}$, $H_{5''}$), 3.39, 3.37, 3.32 (s's, NMe's, OMe), 1.51, 1.33 (Me's); ^{13}C NMR (CDCl$_3$) δ 162.70 (C_4), 151.49 (C_2), 141.63 (C_6), 112.70 (C_5), 111.24 (C(Me)$_2$), 96.72 (OCH_2O), 85.05, 82.85, 81.98, 81.60, ($C_{1'}$–$C_{4'}$), 66.22 ($C_{5'}$), 55.22 (OMe), 37.07 (N_1 Me), 27.81 (N_3 Me), 26.35, 24.83 (Me's); mass spectrum, m/z (relative intensity) 357 (0.6, MH$^+$), 341 (0.6, M$^+$· – CH$_3$), 45 (100, $CH_3OCH_2^+$); calcd for $C_{16}H_{24}N_2O_7$ + H, 357.1662, found, 357.1634.

(3aα,4α,6aα)-Tetrahydro-4-(4-methoxy-1-phenyl)-2′,2′-dimethylfuro[3,4-*d*]-1′,3′-dioxole (8) from 4-(2′,5′-dihydrofuran-2′-yl)methoxybenzene (**7**)[3e] (70 mg, 0.39 mmol) according to the procedure described for the preparation of **2** and **3**. Flash chromatography using ether/petroleum ether (1:1) as eluant gave 59 mg (59%) of pure **8** as a clear oil: ^{1}H NMR (CDCl$_3$) δ 7.35–7.20 (m, 2 Ar H's), 6.95–6.80 (m, 2 Ar H's), 5.07 (br s, $H_{1'}$), 4.81 (br s, $H_{2'}$, $H_{3'}$), 4.01 (m, $H_{4'}$, $H_{4''}$), 3.79 (s, OCH_3), 1.58, 1.36 (s's, $CH_{3'}$ s); ^{13}C NMR (CDCl$_3$) δ 159.06, 130.64, 126.93, 114.01 (C_1–C_6), 113.06 (C(Me)$_2$), 86.92, 85.16, 81.23 ($C_{1'}$,$C_{2'}$,$C_{3'}$), 72.68 ($C_{4'}$), 55.29 (OMe), 26.76, 25.14 (Me's). Anal. Calcd for $C_{14}H_{18}O_4$: C, 67.2; H, 7.25. Found: C, 67.0; H, 7.15.

(3aα,4α,6aα)-Tetrahydro-4-(2-methoxy-1-naphthalenyl)-2′,2′-dimethylfuro[3,4-*d*]-1′,3′-dioxole (10) from 1-(2′,5′-dihydrofuran-2′-yl)-2-methoxynapthalene (**9**,[3e] 141 mg, 0.62 mmol) according to the procedure described for the preparaton of **2** and **3**. Flash chromatography using ether as eluant followed by recrystallization from ether afforded 158 mg (85%) of **10** melting at 148–149 °C: ^{1}H NMR (CDCl$_3$) δ 8.30–7.15 (m, Ar H's), 5.95 (d, J = 2.1 Hz, $H_{1'}$), 5.39–5.00 (m, $H_{2'}$, $H_{3'}$), 4.32–3.98 (m, $H_{4'}$, $H_{4''}$), 3.92 (s, OMe), 1.68, 1.42 (s's, Me's); ^{13}C NMR (CDCl$_3$) δ 154.74, 133.12, 130.63, 129.44, 128.47, 126.95, 123.59, 122.95, 119.20, 113.30 (C_1–C_{10}), 112.76 (C(Me)$_2$), 85.51, 82.47, 81.01 ($C_{1'}$–$C_{3'}$), 74.29 ($C_{4'}$), 56.25 (OMe), 27.00, 25.10 (Me's). Anal. Calcd for $C_{18}H_{20}O_4 \cdot {}^1/_2H_2O$: C, 69.9, H, 6.79. Found: C, 70.0; H, 6.76.

Deprotecton of 5. Preparation of 1,3-Dimethyl-α-pseudouridine (11). A mixture of **5** (65 mg, 0.18 mmol), 10% hydrochloric acid (1.5 mL), and methanol (50 mL) was stirred at room temperature for 30 min. The volatiles were evaporated in vacuo, and the crude product was purified by using preparative TLC (chloroform/methanol, 9:1). Trituration with ether afforded amorphous **11** (39 mg, 80%), softening at 115 °C and melting at 189–190 °C: ^{1}H NMR (D$_2$O) δ 7.64 (d, J = 1.1 Hz, H_6), 5.05 (m, $H_{1'}$), 4.45–4.22 (m, $H_{2'}$, $H_{3'}$), 4.10–3.55 (m, $H_{4'}$, $H_{5'}$, $H_{5''}$); 3.45, 3.29 (NMe's); ^{13}C NMR (D$_2$O) δ 165.16 (C_4), 154.10 (C_2), 144.22 (C_6), 110.40 (C_5), 81.98, 77.76, 73.26, 72.68 ($C_{1'}$–$C_{4'}$), 62.67 ($C_{5'}$), 38.54 (N_1 Me); 29.05 (N_3 Me). Anal. Calcd for $C_{11}H_{16}N_2O_6 \cdot {}^1/_2H_2O$: C, 47.0; H, 6.09; N, 9.95. Found: C, 46.6; H, 6.28; N, 9.69.

N,N-Dimethylation of α-Pseudouridine (12). Alternative Preparation of 11. A mixture of α-pseudouridine (50 mg, 0.20 mmol) and *N*,*N*-dimethylformamide dimethyl acetal (10 mL) was heated at 100 °C for 1.5 h. Evaporaton of volatiles in vacuo followed by preparative TLC (chloroform/methanol, 9:1) afforded 42 mg (78%) of **11**, identical with the product obtained by deprotection of **5** (see above).

5-(4-Hydroxybutyl)-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (13). A mixture of **1** (134 mg, 0.64 mmol), palladium (10%) on activated carbon (20 mg), and methanol (100 mL) was shaken under hydrogen (30 psi) for 2 h. Filtraton (Celite) and evaporaton of volatiles in vacuo gave white crystals, which were rinsed with ether: yield 121 mg (90%); mp 116–117 °C; ^{1}H NMR (CDCl$_3$) δ 6.95 (br s, H_6), 3.70–3.50 (m, 2 H), 3.33, 3.28 (s's, NMe's), 2.60 (br s, OH), 2.40–2.18 (m, 2 H), 1.68–1.42 (m, 4 H); ^{13}C NMR

($CDCl_3$) δ 163.73 (C_4), 151.65 (C_2), 139.08 (C_6), 113.46 (C_5), 62.10 ($C_{4'}$), 36.64 (N_1 Me), 27.81 (N_3 Me), 31.93, 26.89, 24.67 ($C_{1'}$–$C_{3'}$); mass spectrum, *m/z* (relative intensity) 212 (23, $M^{+\cdot}$). Anal. Calcd for $C_{10}H_{16}N_2O_3$: C, 56.6; H, 7.60; N, 13.20. Found: C, 56.4; H, 7.43; N, 12.97.

(*S*)-5-[4-Hydroxy-5-(methoxymethoxy)pentyl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (14). A mixture of **4** (92 mg, 0.33 mmol), palladium (10%) on activated carbon (20 mg), and methanol (50 mL) was shaken under hydrogen (35 psi) for 2 h. Filtration (Celite) and evaporation of volatiles in vacuo gave an oil. Chromatography (preparative TLC, ethyl acetate) afforded 64 mg (70%) of **14** as an oil: ^1H NMR ($CDCl_3$) δ 6.96 (s, H_6), 4.64 (s, OCH_2O), 3.90–3.40 (m, 3 H), 3.36 (s, OMe, NMe), 3.33 (s, NMe), 2.45–2.18 (m, 2 H), 1.75–1.30 (m, 4 H); ^{13}C NMR ($CDCl_3$) δ 163.68 (C_4), 151.74 (C_2), 139.03 (C_6), 113.43 (C_5), 96.99 (OCH_2O), 73.05 ($C_{5'}$), 70.23 ($C_{4'}$), 55.60 (OMe), 36.75 (N_1 Me), 27.92 (N_3 Me), 32.52, 27.15, 24.45 (C_1–$C_{3'}$); mass spectrum, *m/z* (relative intesnity) 286 (10, $M^{+\cdot}$), 255 (31, $M^{+\cdot} - CH_3O$); calcd for $C_{13}H_{22}N_2O_5$, 286.1529, found, 286.1548.

5-(Tetrahydro-2′-furanyl)-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (15). A mixture of **1** (75 mg, 0.36 mmol), palladium (10%) on activated carbon (20 mg), and tetrahydrofuran (20 mL) was shaken under hydrogen (37 psi) for 1.5 h. Filtraton (Celite) and evaportion in vacuo gave an oil. Purification using preparative TLC (ether) afforded 56 mg (75%) of **15**: mp 94–95 °C; ^1H NMR ($CDCl_3$) δ 7.20 (d, *J* = 1.1 Hz, H_6), 4.88–4.65 (m, $H_{1'}$), 4.15–3.68 (m, $H_{4'}$, $H_{4''}$), 3.37, 3.31 (s's, NMe's), 2.60–1.50 (m, 4 H); ^{13}C NMR ($CDCl_3$) δ 162.38 (C_4), 151.68 (C_2), 138.14 (C_6), 115.17 (C_5), 74.59 ($C_{1'}$), 68.33 ($C_{4'}$), 36.89 (N_1 Me), 27.63 (N_3 Me), 32.25, 25.59 ($C_{2'}$, $C_{3'}$). Anal. Calcd for $C_{10}H_{14}N_2O_3$: C, 57.1; H, 6.71; N, 13.32. Found: C, 57.1; H, 6.43; N, 13.07.

(2′*S*)-*trans*-5-[Tetrahydro-5′-[(methoxymethoxy)methyl]-2′-furanyl]-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione (16). A mixture of **4** (70 mg, 0.25 mmol), palladium (10%) on activated carbon (20 mg), and tetrahydrofuran (125 mL) was shaken under hydrogen (35 psi) for 1 h. Filtration (Celite) and evaporation of volatiles in vacuo gave an oil. Chromatography (preparative TLC, ethyl acetate) affoded 60 mg (85%) of **16**: ^1H NMR ($CDCl_3$) δ 7.30 (d, H_6), 5.00–4.75 (m, $H_{1'}$), 4.68 (s, OCH_2O), 4.45–4.20 (m, $H_{4'}$), 3.67–3.50 (m, $H_{5'}$, $H_{5''}$), 3.40, 3.38, 3.30 (s's, NMe's, OMe), 2.65–1.52 (m, 4 H); ^{13}C NMR ($CDCl_3$) δ 162.32 (C_4), 151.62 (C_2), 138.27 (C_6), 114.52 (C_5), 96.56 (OCH_2O), 78.11 ($C_{4'}$), 74.59 ($C_{1'}$), 70.17 ($C_{5'}$), 55.17 (OMe), 36.83 (N_1 Me), 32.63, 28.27 ($C_{2'}$, $C_{3'}$), 27.59 (N_3 Me); mass spectrum, *m/z* (relative intensity) 284 (2, $M^{+\cdot}$), 253 (2, $M^{+\cdot} - CH_3O$); calcd for $C_{13}H_{20}N_2O_5$, 284.1372, found, 284.1370.

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Iodine Chloride as an Intermediate for α Iodination of Aliphatic Acids with Iodine–Thionyl Chloride[1]

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Thus far two methods are known for the one-step α iodination of aliphatic acids using molecular iodine: (a) Chlorosulfonic acid-promoted iodination in 1,2-dichloroethane via a hypothetic intermediate of monoacyl sulfate,[3] $RR'CHCO_2SO_2H$ and (b) Harpp's iodination with thionyl chloride as a solvent.[4]

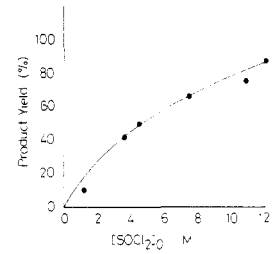

Figure 1. Effect of initial concentration of $SOCl_2$ on the product yield for α iodination of propionyl chloride with iodine in 1,2-dichloroethane at 80 °C for 6 h; $[CH_3CH_2COCl]_0$ = 1.52 M; $[I_2]_0$ = 0.75 M.

Acyl chlorides, which should be formed by the reaction of carboxyic acids with $SOCl_2$ in the Harpp's method, do not react with molecular iodine in solvents other than $SOCl_2$ such as 1,2-dichloroethane and acetonitrile. This suggests that $SOCl_2$ is not only a solvent but that it also plays an unknown role in the iodination. The present paper intends to clarify the mechanism of this $SOCl_2$ promoted α iodination of aliphatic acids.[4]

Results and Discussion

Effect of $SOCl_2$ on α Iodination of Acyl Chloride with Molecular Iodine. Propionyl chloride was allowed to react with half an equivalent amount of iodine in a mixture of 1,2-dichloroethane (EDC) and $SOCl_2$ at 80 °C for 6 h. The yields of α-iodopropionyl chloride were plotted against the initial concentration of $SOCl_2$ and are shown in Figure 1. The figure shows that the yield increases with increasing $[SOCl_2]_0$ (i.e., initial concentration of $SOCl_2$) and that $SOCl_2$ is not a solvent, but participates in the iodination.

Formation of Iodine Chloride in Solution of $SOCl_2$–I_2. Spectrophotometric Evidence. A dilute (below 8.7×10^{-4} M) solution of iodine in $SOCl_2$ has an absorption maximum at 500 nm (ε 910), but the maximum shifts at room temperature to shorter wavelength, down to 450 nm after 12 h, which is close to λ_{max} 430 nm (ε 120) of ICl in $SOCl_2$. Whereas, no change of spectrum was observed with ICl dissolved in $SOCl_2$. These observations suggest that I_2 is gradually transformed to ICl in $SOCl_2$ solution and stabilized at room temperature. Addition of water to this pale yellow $SOCl_2$ solution of ICl generated purple molecular iodine. This is explicable by reactions 1a,b.

$$SOCl_2 + H_2O \rightarrow SO_2 + 2HCl \quad (1a)^5$$

$$2ICl + 2H_2O + SO_2 \rightarrow I_2 + 2HCl + H_2SO_4 \quad (1b)^6$$

No color change was observed on heating a 10^{-2} M I_2 solution of $SOCl_2$ at 80 °C, and the purple color of iodine appeared on heating a 10^{-2} M ICl solution of $SOCl_2$ in EDC

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