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Nucleophilic Addition of Benzenethiol to 1′,2′-Unsaturated Nucleosides: 1′-*C*-Phenylthio-2′-deoxynucleosides as Anomeric Radical Precursors

Hiroki Kumamoto, Miki Murasaki, Kazuhiro Haraguchi, Aki Anamura, and Hiromichi Tanaka*

School of Pharmaceutical Sciences, Showa University, 1−5−8 Hatanodai, Shinagawa-ku, Tokyo 142-8555, Japan

hirotnk@pharm.showa-u.ac.jp

Received March 19, 2002

The addition reaction of benzenethiol to the glycal portion of 1′,2′-unsaturated uridine proceeds efficiently in the presence of Et_3N. The mechanism involves nucleophilic attack of thiolate at the anomeric position in the rate-determining step, wherein conjugation between the nucleobase and the glycal portion is crucial. The derivative having a methyl group either at the 2′- or 6-position did not undergo this addition reaction, due to their sterically prohibited coplanarity. The 1′,2′-unsaturated derivatives of thymine and adenine can also be used as substrates for this addition reaction. It was also shown that the resulting 1′-*C*-phenylthio-2′-deoxynucleosides serve as precursors for radical-mediated C−C bond formation at the anomeric position.

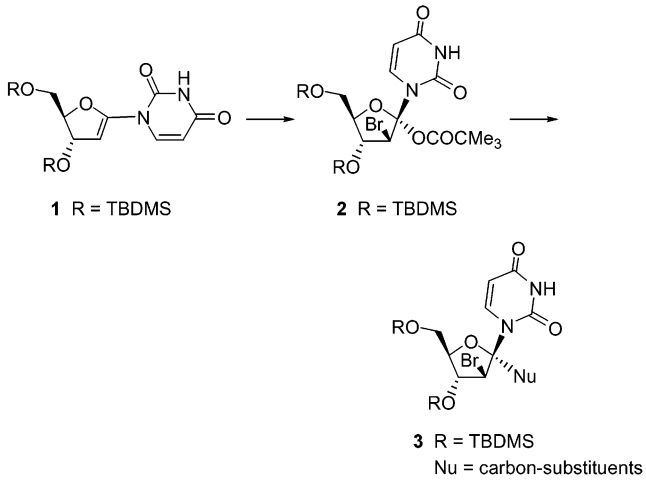
Introduction

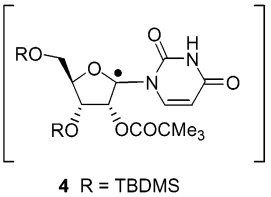
Although interest regarding the addition reaction of thiols to C−C double bonds have mostly been devoted to those operated by a free radical chain mechansm,[1] the reaction also occurs by the usual electrophilic ionic mechanism. Parham and DeLaitsch reported that, in the presence of a catalytic amount of anhydrous HCl in Et_2O, benzenethiol reacts with 3,4-dihydro-2*H*-pyran to yield phenyl 2-tetrahydropyranyl sulfide, albeit at an appreciably slower rate than does the oxygen counterpart phenol.[2]

In our previous studies on the chemistry of the 1′,2′-unsaturated uridine, 1-(2-deoxy-D-*erythro*-pent-1-enofuranosyl)uracil,[3−5] it was shown that the 3′,5′-bis-*O*-*tert*-butyldimethylsilyl (TBDMS) derivative **1** undergoes electrophilic addition (bromo-pivaloyloxylation) to give **2** which can be used as a common intermediate for the synthesis of 1′-*C*-branched derivatives **3** by reacting with organosilicon or organoaluminum reagents (Scheme 1).[3] It was also shown that **2** undergoes radical-mediated 1,2-acyloxy migration to form an anomeric radical **4**.[4]

In the present study, the introduction of a radical precursor, a phenylthio group, to the anomeric position of **1** and other 1′,2′-unsaturated nucleosides was investigated. Also described here is use of the resulting 1′-*C*-phenylthio-2′-deoxynucleosides as anomeric radical precursors, which allows the synthesis of 1′-*C*-branched 2′-deoxynucleosides.

SCHEME 1





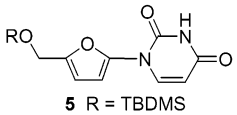
Addition of Benzenethiol to 1′,2′-Unsaturated Nucleosides. The starting material **1** can be prepared from 3′,5′-bis-*O*-TBDMS-O^2,2′-anhydrouridine either by

(1) Stacey, F. W.; Harris, J. F., Jr. In *Organic Reactions*; 1963; Vol. 13, Chapter 4.
(2) Parham, W. E.; DeLaitsch, D. M. *J. Am. Chem. Soc.* **1954**, *76*, 4962−4965.
(3) Itoh, Y.; Haraguchi, K.; Tanaka, H.; Gen, E.; Miyasaka, T. *J. Org. Chem*. **1995**, *60*, 656−662.
(4) Itoh, Y.; Haraguchi, K.; Tanaka, H.; Matsumoto, K.; Nakamura, K. T.; Miyasaka, T. *Tetrahedron Lett*. **1995**, *36*, 3867−3870.
(5) Kumamoto, H.; Shindoh, S.; Tanaka, H.; Itoh, Y.; Haraguchi, K.; Gen, E.; Kittaka, A.; Miyasaka, T.; Kondo, M.; Nakamura, K. T. *Tetrahedron* **2000**, *56*, 5363−5371.

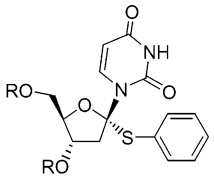
10.1021/jo0201934 CCC: $22.00
Published on Web 07/26/2002

the original method of Robins and Trip[6] or by the method reported from our laboratory: the anhydro-bond cleavage with $(PhSe)_2/LiAlH_4$ followed by oxidative elimination of PhSeOH.[7]

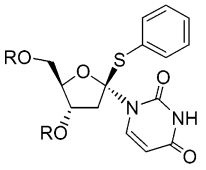
Compound **1** has the inherent propensity to undergo aromatization to form the furan derivative **5**[8] and shows the UV absorption maximum (λ_{max}) in MeOH at a significantly longer wavelength of 276 nm as compared with those of usual uridine analogues, for example, 2′,3′,5′-tris-*O*-TBDMS-uridine (λ_{max} in MeOH: 262 nm). In our recent study on the synthesis of the 2′-substituted derivatives of **1**,[5] it was shown that these characteristic properties of **1**, both chemical and spectroscopic, can be attributable to its planar disposition between the base and glycal moieties.



5 R = TBDMS



6β R = TBDMS

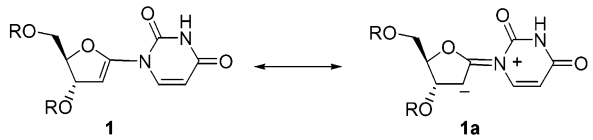


6α R = TBDMS

Our major concern in starting the present study with the introduction of a phenylthio group as a radical precursor to the anomeric position of **1** was the anticipated formation of the furan derivative **5** which would be accelerated by the acidic reagent benzenethiol (pK_a 6.615).[9] In fact, even when **1** was reacted with PhSH (15 equiv) in CH_2Cl_2 in the absence of any additional acid catalyst like anhydrous HCl, **5** was formed in 21% yield. Although this reaction also gave the desired adduct **6** (a mixture of two diastereomers: **6*β*/6α** = 27/73)[10] in 50% yield, the progress of the addition reaction was extremely sluggish and consequently required stirring for 5 days at room temperature.

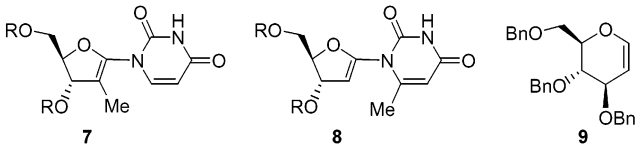
In contrast, the presence of Et_3N (5 equiv) in the above reaction mixture greatly enhanced the reaction rate to give **6** (**6*β*/6α** = 9/91) in 87% yield after only 1 h with no detectable amount of **5** being formed. The highest yield of **6** (94%, **6*β*/6α** = 15/85) was observed when the reaction was carried out in CH_3CN (PhSH, 15 equiv; Et_3N, 5 equiv) at room temperature for 1 h.[11] It is worth noting that the reaction time for completion of this addition reaction depends on the acidity of benzenethiols. Thus, the use of *p*-nitrobenzenethiol (pK_a 4.715)[9] shortened the reaction time to 0.5 h (yield of adduct: 88%), while *p*-methoxybenzenethiol (pK_a 6.775)[9] required 5 h (yield of adduct: 98%) for completion. These results suggest that the efficient addition of PhSH to **1** takes place through a nucleophilic ionic mechanism. This features conjugation between the base and glycal moieties, shown as the resonance structure **1a** in Scheme 2, that is crucial for the nucleophilic attack of benzenethiolate in the rate-determining step.

SCHEME 2



1 **1a**

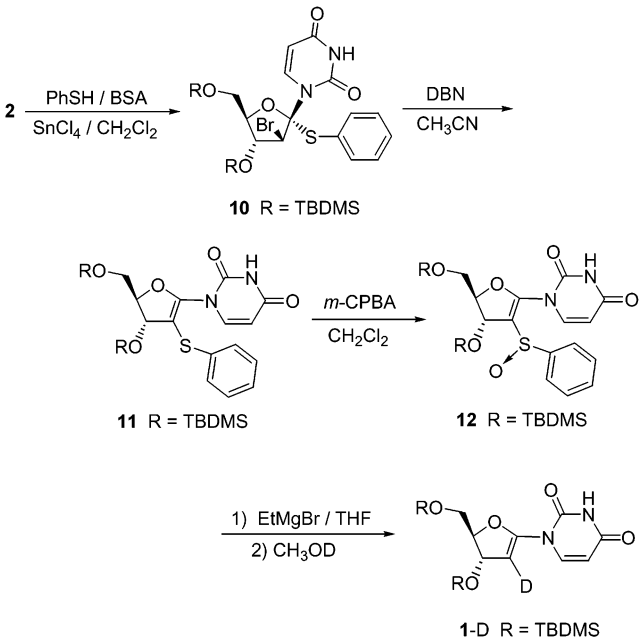
Such conjugation is not feasible in the cases of the 2′-substituted and 6-substituted derivatives of **1**, because these substituents by occupying *ortho* position of the N1−C1′ pivot bond prevent the molecule from taking a coplanar conformation.[5] When the 2′-methyl derivative **7** (λ_{max} in MeOH: 255 nm) or the 6-methyl derivative **8** (λ_{max} in MeOH: 257 nm) was reacted with PhSH in CH_3CN in the presence of Et_3N, only recovery of the starting material was observed (**7**, 73%;[12] **8**, 93%). It was also confirmed that a simple glycal such as 3,4,6-tri-*O*-benzylglucal (**9**) does not react with PhSH under these conditions.



7 **8** **9**

To investigate stereochemical aspects (*syn*- or *anti*-addition) of this reaction, the 2′-deuterated derivative (**1**-D) was prepared from **1** as shown in Scheme 3. Compound **2** prepared in our previous study[3] was reacted with silylated PhSH in the presence of $SnCl_4$ to give **10**

SCHEME 3



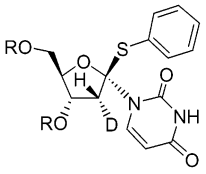
10 R = TBDMS

11 R = TBDMS **12** R = TBDMS

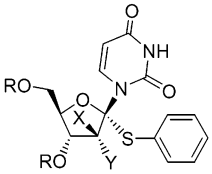
1-D R = TBDMS

(6) Robins, M. J.; Trip, E. M. *Tetrahedron Lett.* **1974**, 3369−3372.
(7) Haraguchi, K.; Tanaka, H.; Maeda, H.; Itoh, Y.; Saito, S.; Miyasaka, T. *J. Org. Chem.* **1991**, *56*, 5401−5408.
(8) For physical data of **5**, see ref 7.
(9) Data (measured in water at 25 °C) taken from the following report: De Maria, P.; Fini, A.; Hall, F. M. *J. Chem. Soc., Perkin Trans. 2* **1973**, 1969−1971.
(10) The depicted stereochemistry of **6*β*** and **6α** was determined by the following NOE data: **6*β*** (1% between H-5′ and H-6; 3% between H-4′ and *ortho*-proton of SPh); **6α** (1% between H-5′ and *ortho*-proton of SPh).
(11) A similar anomer ratio was observed when 3′,5′-*O*-(di-*tert*-butylsilylene) derivative was reacted with PhSH under these reaction conditions (yield 75%, *β*/α = 13/87).

stereoselectively in 86% yield. This compound was found to be rather unstable, and further treatment with DBN in CH_3CN gave the 2′-*C*-phenylthio-1′,2′-unsaturated uridine (**11**) in 80% yield as a result of 1,2-migration of the phenylthio group. Oxidation of **11** with *m*-CPBA gave the sulfoxide **12** (89%). Deuteration at the 2′-position was carried out based on the reported ligand exchange reaction of sufoxides[13] by reacting **12** with EtMgBr and then by quenching with CH_3OD. Compound **1**-D was obtained in 71% yield with a deuterium incorporation of 57%.



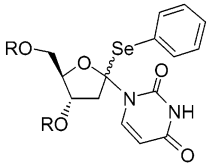
6α-D R = TBDMS



6β-D R = TBDMS
syn-adduct: X = D, Y = H
anti-adduct: X = H, Y = D

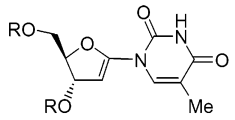
The addition reaction of PhSH to **1**-D (Et_3N/CH_3CN, for 1 h) was followed by HPLC separation of the resulting adducts (**6*β***-D/**6α**-D = 15/85). Based on the analysis of their ^{1}H NMR spectra, it became apparent that exclusive *syn*-addition had taken place for the major isomer **6α**, while both the *syn*- and *anti*-pathway (*syn*/*anti* = 1.8/1.0) had been operative in the formation of **6*β***. We have no satisfactory explanation for these results, but as far as formation of the major adduct **6α** is concerned, it would be possible to say that the α-face of the incipient C2′-anion is more encumbered than the *β*-face due to the presence of both the uracil base and the 3′-*O*-silyl group.

One would readily anticipate that the phenylselenenyl group can also serve as an anomeric radical precursor. The adduct **13** was prepared in 96% yield (*β*/α = 17/83) by reacting **1** with benzeneselenol under the same reaction conditions as those employed for the formation of **6**. Compound **13** was found, however, to be too labile, liberating benzeneselenol upon heating in refluxing benzene to yield **1**.[14]

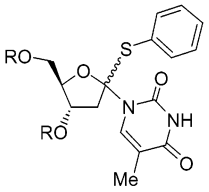


13 R = TBDMS

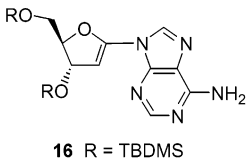
The present addition reaction also works for other 1′,2′-unsaturated nucleosides. The thymine derivative **14**[15] reacts with PhSH/Et_3N in CH_3CN at room temperature to give **15** (*β*/α = 6/94) in 88% yield after 1 h. The 1′,2′-unsaturated adenosine **16**,[16] on the other hand, required heating in refluxing CH_3CN for 18 h to form the adduct **17** (76%, *β*/α = 24/76).



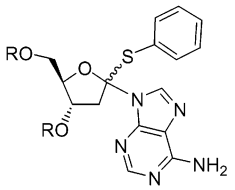
14 R = TBDMS



15 R = TBDMS



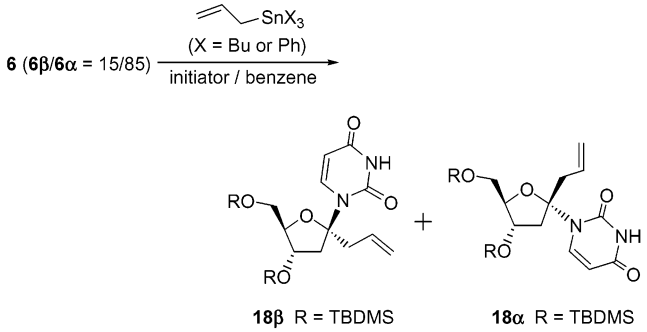
16 R = TBDMS



17 R = TBDMS

Radical Reactions of 1′-*C*-Phenylthio-2′-deoxyribonucleosides. As shown in Scheme 4, radical-mediated allylation at the anomeric position was carried out

SCHEME 4



in benzene by using **6** (**6*β***/**6α** = 15/85) and allyl(tributyl)-tin or allyl(triphenyl)tin under several different reaction conditions: Et_3B/0 °C; $(Bu_3Sn)_2$/*hν*/rt; AIBN/80 °C. Although the yield of the product (**18**) varied considerably (51%−82%) depending on the conditions used, there was no significant difference in the ratio of **18*β***/**18α** (67/33−72/28). The highest yield of 82% was attained with a diastereomeric ratio of **18*β***/**18α** = 68/32 upon reacting with allyl(tributyl)tin in the presence of AIBN in refluxing benzene for 2 h. Compounds **18*β*** and **18α** were isolated by HPLC separation (hexane/EtOAc = 5/1, **18*β*** t_R 41 min; **18α** t_R 40 min). Predominant formation of *β*-anomer was also observed in the allylation of **15** and **17**, forming **19*β*** (combined yield 81%, *β*/α = 68/32) and **20*β*** (combined yield 72%, *β*/α = 71/29), respectively, as the major product.[17]

Chatgilialoglu et al. reported that the 2′-deoxyuridin-1-yl radical derived from 1′-*C*-(*tert*-butyl)carbonyl-2′-

(12) This particular reaction was carried out in refluxing CH_3CN for 12 h.

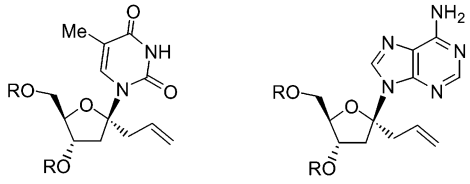
(13) Satoh, T.; Takano, K.; Ota, H.; Someya, H.; Matsuda, K.; Koyama, M. *Tetrahedron* **1998**, *54*, 5557−5574.

(14) Introduction of a phenylselenenyl group to the anomeric position of a 2′- ketouridine has recently been reported: Kodama, T.; Shuto, S.; Nomura, M.; Matsuda, A. *Chem. Eur. J.* **2001**, *7*, 2332−2340.

(15) For the preparation of **14** from 3′,5′-bis-*O*-(*tert*-butyldimethylsilyl)- O^2,2′-anhydroribothymidine: Yoshimura, Y.; Kano, F.; Miyazaki, S.; Ashida, N.; Sakata, S.; Haraguchi, K.; Itoh, Y.; Tanaka, H.; Miyasaka, T. *Nucleosides Nucleotides* **1996**, *15*, 305.

(16) For the preparation of **16**: Gimisis, T.; Ialongo, G.; Chatgilialoglu, C. *Tetrahedron* **1998**, *54*, 573−592.

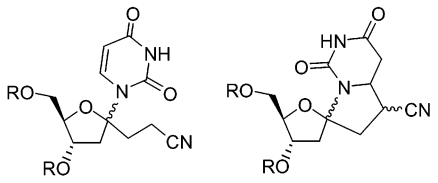
(17) Stereochemistry of the *β*- and α-anomers of **18**, **19**, and **20** was determined by the following NOE data: **18*β*** (1% between H-3′ and H− 6); **18α** (9% between H-4′ and H-6); **19*β*** (1% between H-3′ and H-6); **19α** (10% between H-4′ and H-6); **20*β*** (1% between H-3′ and H-8); **20α** (9% between H-4′ and H-8).



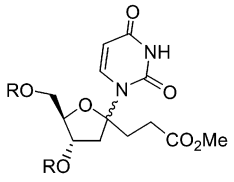
19β R = TBDMS **20β** R = TBDMS

deoxyuridine[18] as being pyramidal based on EPR spectroscopy.[19] Also reported was the observation that both β- and α- anomers of this radical precursor gave an identical β/α-ratio (65/35) of 2′-deoxyuridine upon irradiation in the presence of various thiols as hydrogen donors.[20] These facts have led to the proposal that the 2′-deoxyuridin-1-yl radical exists in equilibrium of two sp^3-hybridized species with opposite configuration. This was further supported in the present reaction of **6**. Thus, when **6*β*** and **6α** were reacted separately with allyl(tributyl)tin, exactly the same ratio of **18*β*/18α** = 68/32 resulted.

Finally, radical reactions of **6** with acceptors such as acrylonitrile and methyl acrylate were carried out by using Bu_3SnH (1.0 equiv)/AIBN (0.4 equiv) in refluxing benzene. In these reactions, incipient radical formed by addition of the anomeric radical to the acceptor has a good chance to cyclize across the 5,6-double bond in a 5-*exo*-trig manner.[21] In fact, when a refluxing mixture of **6** and acrylonitrile (5 equiv) was treated with Bu_3SnH/AIBN added dropwise over 4 h via a motor-driven syringe and then the reaction continued for further 3 h, in addition to the desired product **21** (24%), the 6,1′-ethano-bridged product **22** (41%, a diastereomeric mixture) was



21 R = TBDMS **22** R = TBDMS



23 R = TBDMS

also formed. Simply by adding Bu_3SnH/AIBN over a considerably shorter time of 1 h, formation of **22** was suppressed, and **21** was isolated in 83% yield (β/α = 74/26). In the reaction with methyl acrylate, to ensure a high-yield of **23** (72%, β/α = 70/30), it was necessary to add a benzene solution of AIBN dropwise to a refluxing mixture containing **6**, the acceptor, and Bu_3SnH.[22]

Conclusion

Characteristic coplanar disposition of nucleobase and glycal portions of 1′,2′-unsaturated nucleosides has allowed an efficient nucleophilic addition reaction with PhSH accelerated by Et_3N. Through this addition reaction, 1′-*C*-phenylthio derivatives of 2′-deoxyuridine, thymidine, and 2′-deoxyadenosine were prepared as an anomeric mixture with the respective α-anomer being preponderant. The phenylthio group of these adducts serves as a radical precursor upon reacting with allyl(tributyl)tin, acrylonitrile/Bu_3SnH, and methyl acrylate/Bu_3SnH in refluxing benzene in the presence of AIBN. The whole reaction sequence constitutes an efficient entry to 1′-*C*-branched 2′-deoxynucleosides.

Experimental Section

Melting points are uncorrected. ^1H NMR was measured at 500 MHz. Chemical shifts are reported relative to Me_4Si. Mass spectra (MS) were taken in FAB mode with *m*-nitrobenzyl alcohol as a matrix. Column chromatography was carried out on silica gel (Silica Gel 60) unless otherwise noted. Thin-layer chromatography (TLC) was performed on silica gel (precoated silica gel plate F_{254}). HPLC was carried out on a 2 × 25 cm column.

3′,5′-Bis-*O*-(*tert*-butyldimethylsilyl)-2′-deoxy-1′-*C*-phenylthiouridine (6*β*) and Its Anomer (6α). A mixture of **1** (100 mg, 0.22 mmol), PhSH (0.34 mL, 3.3 mmol), and Et_3N (0.15 mL, 1.1 mmol) in CH_3CN (3.0 mL) were stirred at room temperature for 1 h under positive pressure of dry Ar. The reaction mixture was partitioned between $CHCl_3$ and saturated aqueous $NaHCO_3$. Column chromatography (hexane/EtOAc = 3/1) of the organic layer gave **6** (117 mg, 94%, powder) as a mixture of **6*β*/6α** = 27/73 (calculated by integrating H-5). HPLC (hexane/EtOAc = 2/1) separation of this mixture gave analytically pure **6*β*** (t_R 18 min, foam) and **6α** (t_R 14 min, solid). Physical data of **6*β***: UV (MeOH) λ_{max} 265 nm (ϵ 9400), λ_{min} 241 nm (ϵ 2400); ^1H NMR ($CDCl_3$) δ 0.03, 0.08, and 0.10 (12H, each as s), 0.84 and 0.92 (18H, each as s), 2.77 (1H, dd, *J* = 4.0 and 15.0 Hz), 3.03 (1H, dd, *J* = 7.2 and 15.0 Hz), 3.71 (1H, dd, *J* = 3.5 and 11.5 Hz), 3.80 (1H, dd, *J* = 2.9 and 11.5 Hz), 4.28−4.33 (2H, m), 5.16 (1H, dd, *J* = 2.5 and 8.1 Hz), 7.09 (1H, d, *J* = 8.1 Hz), 7.25−7.29, 7.35−7.38, and 7.41−7.43 (5H, each as m), 8.36 (1H, br); FAB-MS *m*/*z* 603 (M^+ + K). Anal. Calcd for $C_{27}H_{44}N_2O_5SSi_2$: C, 57.41; H, 7.85; N, 4.96. Found: C, 57.71; H, 8.11; N, 4.89. Physical data of **6α**: mp 161 °C; UV (MeOH) λ_{max} 266 nm (ϵ 10400), λ_{min} 239 nm (ϵ 1900); ^1H NMR ($CDCl_3$) δ −0.01 and 0.10 (12H, each as s), 0.76 and 0.92 (18H, each as s), 2.58 (1H, dd, *J* = 5.5 and 14.5 Hz), 3.37 (1H, dd, *J* = 2.5 and 14.5 Hz), 3.41 (1H, dd, *J* = 6.4 and 11.0 Hz), 3.66 (1H, dd, *J* = 4.6 and 11.0 Hz), 4.01 (1H, ddd, *J* = 2.3, 4.6, and 6.4 Hz), 4.30 (1H, ddd, *J* = 2.3, 2.5, and 5.5 Hz), 5.34 (1H, dd, *J* = 2.5 and 8.3 Hz), 7.26−7.51 (6H, m), 8.27 (1H, br); FAB-MS *m*/*z* 603 (M^+ + K). Anal. Calcd for $C_{27}H_{44}N_2O_5SSi_2$: C, 57.41; H, 7.85; N, 4.96. Found: C, 57.45; H, 8.00; N, 4.88.

1-[2-Bromo-3,5-bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-1-phenylthio-*β*-D-arabinofuranosyl]uracil (10). A mixture of benzenethiol (0.13 mL, 1.26 mmol) and *N*,*O*-bis(trimethylsilyl)acetamide (0.31 mL, 1.26 mmol) in CH_2Cl_2 (3 mL) was

(18) (a) Goodman, B. K.; Greenberg, M. M. *J. Org. Chem*. **1996**, *61*, 2−3. (b) Greenberg, M. M.; Yoo, D. J.; Goodman, B. K. *Nucleosides Nucleotides* **1997**, *16*, 33−40.

(19) Chatgilialoglu, C.; Gimisis, T.; Guerra, M.; Ferreri, C.; Emanuel, C. J.; Horner, J. H.; Newcomb, M.; Lucarini, M.; Pedulli, G. F. *Tetrahedron Lett*. **1998**, *39*, 3947−3950.

(20) Chatgilialoglu, C.; Ferreri, C.; Bazzanini, R.; Guerra, M.; Choi, S.-Y.; Emanuel, C. J.; Horner, J. H.; Newcomb, M. *J. Am. Chem. Soc.* **2000**, *122*, 9525−9533.

(21) For a recent example: Kumamoto, H.; Ogamino, J.; Tanaka, H.; Suzuki, H.; Haraguchi, K.; Miyasaka, T.; Yokomatsu, T.; Shibuya, S. *Tetrahedron* **2001**, *57*, 3331−3341.

(22) Stereochemistry of the β- and α-anomers of **21** and **23** was determined by the following NOE data: **21*β*** (1% between H-3′ and H-6, 5% between H-5′ and H-6); **21α** (9% between H-4′ and H-6); **23*β*** (1% between H-3′ and H-6); **23α** (10% between H-4′ and H-6).

stirred for 1 h at room temperature under positive pressure of dry Ar and then cooled to −40 °C. After a solution of **2** (400 mg, 0.63 mmol) in CH_2Cl_2 (3 mL) was added dropwise to the above mixture, the reaction was continued for 2 h at −20 °C.

The reaction mixture was partitioned between saturated aqueous $NaHCO_3$ and $CHCl_3$. Column chromatography (hexane/EtOAc = 3/1) of the organic layer gave **10** (348.5 mg, 86%) as a foam, which is rather unstable: ^{1}H NMR ($CDCl_3$) δ 0.08, 0.09, 0.15, and 0.20 (12H, each as s), 0.91 and 0.97 (18H, each as s), 3.87 (1H, dd, J = 5.3 and 11.0 Hz), 3.91 (1H, dd, J = 5.8 and 11.0 Hz), 4.49 (1H, ddd, J = 3.6, 5.3, and 5.8 Hz), 4.65 (1H, d, J = 3.6 Hz), 4.89 (1H, s), 5.24 (1H, dd, J = 2.6 and 8.3 Hz), 7.01 (1H, d, J = 8.3 Hz), 7.26−7.31 (2H, m), 7.36−7.40 (3H, m), 8.13 (1H, br). Without any further characterization, this compound was used for the preparation of **11**.

1-[3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-2-phenylthio-D-*erythro*-pent-1-enofuranosyl]uracil (11). DBN (0.33 mL, 2.65 mmol) was added dropwise to a CH_3CN (8 mL) solution of **10** (341.3 mg, 0.53 mmol) kept at 0 °C under positive pressure of dry Ar. After stirring overnight at room temperature, the reaction mixture was partitioned between brine and EtOAc. Column chromatography (hexane/EtOAc = 3/1) of the organic layer gave **11** (259.6 mg, 87%) as a pale yellow foam: UV (MeOH) λ_{max} 249 nm (ϵ 17400), λ_{min} 230 nm (ϵ 10800); ^{1}H NMR ($CDCl_3$) δ −0.03, 0.08, and 0.09 (12H, each as s), 0.85 and 0.90 (18H, each as s), 3.80 (1H, dd, J = 6.0 and 11.0 Hz), 3.88 (1H, dd, J = 4.4 and 11.0 Hz), 4.53−4.56 (1H, m), 4.93 (1H, d, J = 2.8 Hz), 5.71 (1H, dd, J = 2.2 and 8.2 Hz), 7.12−7.18 (2H, m), 7.23−7.30 (4H, m), 8.32 (1H, br); FAB-MS m/z 563 (M^+ + H). Anal. Calcd for $C_{27}H_{42}N_2O_5SSi_2$: C, 57.61; H, 7.52; N, 4.98. Found: C, 57.57; H, 7.61; N, 4.91.

1-[3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-2-phenylsulfinyl-D-*erythro*-pent-1-enofuranosyl]uracil (12). Compound **11** (188 mg, 0.33 mmol) dissolved in CH_2Cl_2 (6 mL) was kept at −50 °C. A CH_2Cl_2 (3 mL) solution of *m*-CPBA (min 65%, 133.1 mg, 0.5 mmol) was added dropwise to the above solution, and the reaction mixture was stirred for 2 h at −50 °C. The reaction mixture was partitioned between saturated aqueous $NaHCO_3$ and $CHCl_3$. Column chromatography (hexane/EtOAc = 1/1) of the organic layer gave **12** (172.7 mg, 90%, ratio of diastereomers = 88/22) as a foam: UV (MeOH) λ_{max} 257 nm (ϵ 13600), λ_{min} 245 nm (ϵ 13300); ^{1}H NMR ($CDCl_3$) data of the major diastereomer δ −0.32, −0.02, and 0.09 (12H, each as s), 0.73 and 0.91 (18H, each as s), 3.73 (1H, dd, J = 5.6 and 11.2 Hz), 3.80 (1H, dd, J = 4.9 and 11.2 Hz), 4.53 (1H, ddd, J = 2.0, 4.9, and 5.6 Hz), 5.21 (1H, d, J = 2.0 Hz), 5.83 (1H, d, J = 8.0 Hz), 7.38−7.54 (4H, m), 7.80−7.83 (2H, m), 8.27 (1H, br); FAB-MS m/z 579 (M^+ + H). Anal. Calcd for $C_{27}H_{42}N_2O_6SSi_2$: C, 56.02; H, 7.31; N, 4.84. Found: C, 56.15; H, 7.46; N, 4.74.

Preparation of the 2′-Deuterated 1′,2′-Unsaturated Uridine (1-D). A THF solution of EtMgBr (0.96 M, 3.92 mL, 3.76 mmol) was added dropwise to **12** (436.1 mg, 0.75 mmol) in THF (18 mL) kept at −40 °C under positive pressure of dry Ar. After stirring for 1 h, the reaction mixture was treated with MeOD (5 mL) and then partitioned between brine and $CHCl_3$. Florisil column chromatography (hexane/EtOAc = 5/1) of the organic layer gave **1**-D (241.5 mg, 71%) as a powder. The extent of deuterium incorporation (57%) was calculated based on ^{1}H NMR spectroscopy by integrating H-2′.

3′,5′-Bis-*O*-(*tert*-butyldimethylsilyl)-2′-deoxy-1′-*C*-phenylselenouridine (13). This compound was obtained as a mixture of two anomers (β/α = 17/83) in 96% yield by using 15 equiv of PhSeH by the procedure described for the preparation of **6**. HPLC (hexane/EtOAc = 3/1) separation of this mixture gave analytically pure **13*β*** (t_R 12.4 min, foam) and **13α** (t_R 10.8 min, solid). Physical data of **13*β***: UV (MeOH) λ_{max} 267 nm (ϵ 10400), λ_{min} 249 nm (ϵ 7500); ^{1}H NMR ($CDCl_3$) δ −0.01, 0.02, 0.09, and 0.11 (12H, each as s), 0.83 and 0.94 (18H, each as s), 2.89 (1H, dd, J = 6.2 and 15.0 Hz), 2.94 (1H, dd, J = 3.2 and 15.0 Hz), 3.70 (1H, dd, J = 3.6 and 11.2 Hz), 3.75 (1H, dd, J = 3.2 and 11.2 Hz), 4.28−4.34 (2H, m), 5.15 (1H, dd, J = 2.6 and 8.0 Hz), 7.15 (1H, d, J = 8.0 Hz), 7.22−7.28 (2H, m), 7.34−7.38 (1H, m), 7.52−7.55 (2H, m), 7.98 (1H, br); FAB-MS m/z 501 (M^+ − uracil − H). Anal. Calcd for $C_{27}H_{44}N_2O_5SeSi_2$: C, 53.01; H, 7.25; N, 4.58. Found: C, 52.96; H, 7.58; N, 4.87.

Physical data of **13α**: mp 157−159 °C; UV (MeOH) λ_{max} 268 nm (ϵ 10900), λ_{min} 246 nm (ϵ 6800); ^{1}H NMR ($CDCl_3$) δ −0.02 and 0.06 (12H, each as s), 0.75 and 0.90 (18H, each as s), 2.64 (1H, dd, J = 5.1 and 14.8 Hz), 3.17 (1H, dd, J = 6.8 and 11.0 Hz), 3.40 (1H, dd, J = 2.2 and 14.8 Hz), 3.50 (1H, dd, J = 4.6 and 11.0 Hz), 4.02 (1H, ddd, J = 2.1, 4.6, and 6.8 Hz), 4.23 (1H, ddd, J = 2.1, 2.2, and 5.1 Hz), 5.42 (1H, dd, J = 2.5 and 8.5 Hz), 7.26−7.30 (2H, m), 7.37−7.44 (2H, m), 7.60−7.62 (2H, m), 8.16 (1H, br); FAB-MS m/z 501 (M^+ − uracil − H). Anal. Calcd for $C_{27}H_{44}N_2O_5SeSi_2$: C, 53.01; H, 7.25; N, 4.58. Found: C, 53.14; H, 7.42; N, 4.82.

3′,5′-Bis-*O*-(*tert*-butyldimethylsilyl)-1′-*C*-phenylthiothymidine (15*β*) and Its α-Anomer (15α). A mixture of these two anomers (β/α = 24/76, calculated by integrating H-2′) was obtained in 88% yield from **14** by the procedure described for the preparation of **6**. HPLC (hexane/EtOAc = 2/1) separation of this mixture gave analytically pure **15*β*** (t_R 9.0 min, foam) and **15α** (t_R 7.4 min, foam). Physical data of **15*β***: UV (MeOH) λ_{max} 268 nm (ϵ 16100), λ_{min} 247 nm (ϵ 11800); ^{1}H NMR ($CDCl_3$) δ 0.04, 0.08, and 0.10 (12H, each as s), 0.84 and 0.92 (18H, each as s), 1.54 (3H, d, J = 1.3 Hz), 2.75 (1H, dd, J = 3.9 and 15.0 Hz), 3.03 (1H, dd, J = 7.6 and 15.0 Hz), 3.73 (1H, dd, J = 4.0 and 11.6 Hz), 3.83 (1H, dd, J = 2.8 and 11.6 Hz), 4.26−4.29 (1H, m), 4.32−4.35 (1H, m), 6.90 (1H, q, J = 1.3 Hz), 7.25−7.29 (2H, m), 7.32−7.36 (1H, m), 7.42−7.44 (2H, m), 8.20 (1H, br); FAB-MS m/z 617 (M^+ + K). Anal. Calcd for $C_{28}H_{46}N_2O_5SSi_2$: C, 58.09; H, 8.01; N, 4.84. Found: C, 58.29; H, 8.28; N, 4.69. Physical data of **15α**: UV (MeOH) λ_{max} 268 nm (ϵ 13800), λ_{min} 245 nm (ϵ 9500); ^{1}H NMR ($CDCl_3$) δ −0.02 and 0.09 (12H, each as s), 0.74 and 0.92 (18H, each as s), 1.70 (3H, d, J = 1.2 Hz), 2.58 (1H, dd, J = 5.7 and 14.7 Hz), 3.34 (1H, dd, J = 3.1 and 14.7 Hz), 3.35 (1H, dd, J = 6.5 and 11.0 Hz), 3.63 (1H, dd, J = 4.6 and 11.0 Hz), 4.00 (1H, ddd, J = 2.8, 4.6, and 6.5 Hz), 4.22 (1H, ddd, J = 2.8, 3.1, and 5.7 Hz), 7.20 (1H, q, J = 1.2 Hz), 7.28−7.32 (2H, m), 7.35−7.39 (1H, m), 7.51−7.53 (2H, m), 8.16 (1H, br); FAB-MS m/z 617 (M^+ + K). Anal. Calcd for $C_{28}H_{46}N_2O_5SSi_2$: C, 58.09; H, 8.01; N, 4.84. Found: C, 58.25; H, 8.15; N, 4.86.

3′,5′-Bis-*O*-(*tert*-butyldimethylsilyl)-2′-deoxy-1′-*C*-phenylthioadenosine (17*β*) and Its α-Anomer (17α). A mixture of **16** (300 mg, 0.63 mmol), PhSH (0.97 mL, 9.45 mmol), and Et_3N (0.44 mL, 3.15 mmol) in CH_3CN (15 mL) was refluxed for 24 h under atmosphere of dry Ar.

The reaction mixture was partitioned between $CHCl_3$ and saturated aqueous $NaHCO_3$. Column chromatography (hexane/EtOAc = 1/2) of the organic layer gave **17** (280.3 mg, 76%) as a mixture of **17*β*/17α** = 24/76 (calculated by integrating H-2′). HPLC (hexane/EtOAc = 1/1) separation of this mixture gave analytically pure **17*β*** (t_R 29.4 min, solid) and **17α** (t_R 25.9 min, solid). Physical data of **17*β***: mp 145−148 °C; UV (MeOH) λ_{max} 260 nm (ϵ 16100), λ_{min} 238 nm (ϵ 7100); ^{1}H NMR ($CDCl_3$) δ 0.02, 0.05, and 0.08 (12H, each as s), 0.81 and 0.90 (18H, each as s), 2.80 (1H, dd, J = 6.1 and 14.3 Hz), 3.51 (1H, dd, J = 7.3 and 14.3 Hz), 3.74 (1H, dd, J = 3.7 and 11.6 Hz), 3.88 (1H, dd, J = 2.8 and 11.6 Hz), 4.28 (1H, ddd, J = 2.8, 3.7, and 3.8 Hz), 4.34 (1H, ddd, J = 6.1, 5.4, and 7.3 Hz), 5.73 (2H, br), 7.06−7.09 (2H, m), 7.11−7.14 (2H, m), 7.26−7.30 (1H, m), 7.44 and 8.45 (2H, each as s); FAB-MS m/z 588 (M^+ + H). Anal. Calcd for $C_{28}H_{45}N_5O_3SSi_2$: C, 57.20; H, 7.72; N, 11.91. Found: C, 57.39; H, 7.84; N, 11.81. Physical data of **17α**: mp 195−197 °C; UV (MeOH) λ_{max} 260 nm (ϵ 16400), λ_{min} 237 nm (ϵ 6100); ^{1}H NMR ($CDCl_3$) δ −0.26, −0.11, 0.12, and 0.13 (12H, each as s), 0.47 and 0.93 (18H, each as s), 2.65 (1H, dd, J = 5.5 and 14.0 Hz), 3.44 (1H, dd, J = 6.6 and 10.9 Hz), 3.74 (1H, dd, J = 4.2 and 10.9 Hz), 3.75 (1H, dd, J = 1.2 and 14.0 Hz), 4.19 (1H, ddd, J = 1.3, 4.2, and 6.6 Hz), 4.40 (1H, ddd, J = 1.2, 1.3, and 5.5 Hz), 5.48 (2H, br), 7.16−7.19 (2H, m), 7.23−

7.26 (2H, m), 7.29−7.32 (1H, m), 7.60 and 8.44 (2H, each as s); FAB-MS *m*/*z* 588 ($M^+ + H$). Anal. Calcd for $C_{28}H_{45}N_5O_3SSi_2$: C, 57.20; H, 7.72; N, 11.91. Found: C, 57.23; H, 7.78; N, 11.83.

1′-*C*-Allyl-3′,5′-bis-*O*-(*tert*-butyldimethylsilyl)-2′-deoxyuridine (18*β*) and It's α-Anomer (18α). A mixture of **6** (100 mg, 0.18 mmol) and allyl(tributyl)tin (0.17 mL, 0.54 mmol) in benzene (5 mL) was stirred at 80 °C under positive pressure of dry Ar. To this was added a benzene (5 mL) solution of AIBN (12 mg, 0.07 mmol) via a motor-driven syringe over 1 h. The whole reaction mixture was heated with stirring for further 1 h. Evaporation of the solvent followed by column chromatography (hexane/EtOAc = 3/1) gave **18** (73.1 mg, 82%, *β*/α = 68/32, calculated by integrating H-5). Each anomer was isolated by HPLC (hexane/EtOAc = 5/1: **18*β*** t_R 41 min, foam; **18α** t_R 40 min, foam). Physical data of **18*β***: UV (MeOH) λ_{max} 266 nm (ϵ 9400), λ_{min} 232 nm (ϵ 900); ^{1}H NMR ($CDCl_3$) δ 0.03, 0.04, 0.07, and 0.08 (12H, each as s), 0.86 and 0.89 (18H, each as s), 2.48 (1H, dd, J = 3.9 and 14.3 Hz), 2.74 (1H, dd, J = 6.3 and 14.3 Hz), 2.81 (1H, dd, J = 6.0 and 14.2 Hz), 3.05 (1H, dd, J = 8.4 and 14.2 Hz), 3.62 (1H, dd, J = 3.4 and 11.3 Hz), 3.69 (1H, dd, J = 3.8 and 11.3 Hz), 4.08 (1H, ddd, J = 3.4, 3.7, and 3.8 Hz), 4.28 (1H, dd, J = 3.7, 3.9, and 6.3 Hz), 5.04−5.10 (2H, m), 5.56 (1H, dd, J = 1.5 and 8.4 Hz), 5.70−5.78 (1H, m), 7.88 (1H, d, J = 8.4 Hz), 8.12 (1H, br); FAB-MS *m*/*z* 497 ($M^+ + H$), 535 ($M^+ + K$). Anal. Calcd for $C_{24}H_{44}N_2O_5Si_2 \cdot {}^1/_2H_2O$: C, 56.99; H, 8.77; N, 5.54. Found: C, 57.00; H, 8.87; N. 5.44. Physical data of **18α**: UV (MeOH) λ_{max} 265 nm (ϵ 10500), λ_{min} 233 nm (ϵ 2400); ^{1}H NMR ($CDCl_3$) δ −0.01 and 0.08 (12H, each as s), 0.78 and 0.91 (18H, each as s), 2.25 (1H, dd, J = 5.6 and 14.3 Hz), 2.63 (1H, dd, J = 6.9 and 14.1 Hz), 2.94 (1H, dd, J = 1.5 and 14.3 Hz), 3.05 (1H, dd, J = 7.9 and 14.1 Hz), 3.59 (1H, dd, J = 5.2 and 11.0 Hz), 3.70 (1H, dd, J = 3.7 and 11.0 Hz), 3.99−4.02 (1H, m), 4.31 (1H, ddd, J = 1.5, 1.8, and 5.6 Hz), 5.07−5.12 (2H, m), 5.62 (1H, dd, J = 1.7 and 8.5 Hz), 5.67−5.75 (1H, m), 7.66 (1H, d, J = 8.5 Hz), 8.14 (1H, br); FAB-MS *m*/*z* 497 ($M^+ + H$). Anal. Calcd for $C_{24}H_{44}N_2O_5Si_2$: C, 58.02; H, 8.93; N, 5.64. Found: C, 58.10; H, 9.14; N, 5.54.

1′-*C*-Allyl-3′,5′-bis-*O*-(*tert*-butyldimethylsilyl)thymidine (19*β*) and It's α-Anomer (19α). A mixture of these two anomers (**19*β***/**19α** = 68/32, calculated by integrating H-2′) was obtained in 81% yield from **15** by the procedure described for the preparation of **18**, except that the reaction was continued for 3 h after finishing addition of Bu_3SnH. HPLC (hexane/EtOAc = 2/1) separation of this mixture gave analytically pure **19*β*** (t_R 9.4 min, foam) and **19α** (t_R 9.1 min, foam). Physical data of **19*β***: UV (MeOH) λ_{max} 270 nm (ϵ 10200), λ_{min} 238 nm (ϵ 2700); ^{1}H NMR ($CDCl_3$) δ 0.01, 0.03, 0.07, and 0.08 (12H, each as s), 0.84 and 0.89 (18H, each as s), 1.89 (3H, d, J = 1.2 Hz), 2.55 (1H, dd, J = 2.8 and 15.0 Hz), 2.70 (1H, dd, J = 6.0 and 15.0 Hz), 2.80 (1H, dd, J = 6.3 and 15.0 Hz), 3.04 (1H, dd, J = 8.2 and 15.0 Hz), 3.61 (1H, dd, J = 3.7 and 11.3 Hz), 3.65 (1H, dd, J = 4.0 and 11.3 Hz), 4.11 (1H, ddd, J = 3.4, 3.7, and 4.0 Hz), 4.28 (1H, ddd, J = 2.8, 3.4, and 6.0 Hz), 5.02−5.08 (2H, m), 5.70−5.78 (1H, m), 7.65 (1H, q, J = 1.2 Hz), 8.74 (1H, br); FAB-MS *m*/*z* 511 ($M^+ + H$), 549 ($M^+ + K$). Anal. Calcd for $C_{25}H_{46}N_2O_5Si_2$: C, 58.78; H, 9.08; N, 5.48. Found: C, 58.54; H, 9.26; N. 5.35. Physical data of **19α**: UV (MeOH) λ_{max} 271 nm (ϵ 10000), λ_{min} 237 nm (ϵ 2500); ^{1}H NMR ($CDCl_3$) δ −0.02, −0.01, and 0.09 (12H, each as s), 0.76 and 0.92 (18H, each as s), 1.90 (3H, d, J = 1.2 Hz), 2.25 (1H, dd, J = 5.9 and 14.3 Hz), 2.63 (1H, dd, J = 6.9 and 14.0 Hz), 2.90 (1H, dd, J = 2.0 and 14.3 Hz), 3.05 (1H, dd, J = 7.7 and 14.0 Hz), 3.59 (1H, dd, J = 5.5 and 11.0 Hz), 3.70 (1H, dd, J = 3.8 and 11.0 Hz), 4.01 (1H, ddd, J = 1.9, 3.8, and 5.5 Hz), 4.28 (1H, ddd, J = 1.9, 2.0, and 5.9 Hz), 5.08−5.12 (2H, m), 5.66−5.75 (1H, m), 7.48 (1H, q, J = 1.2 Hz), 7.93 (1H, br); FAB-MS *m*/*z* 549 ($M^+ + K$). Anal. Calcd for $C_{25}H_{46}N_2O_5Si_2$: C, 58.78; H, 9.08; N, 5.48. Found: C, 58.57; H, 9.23; N. 5.35.

1′-*C*-Allyl-3′,5′-bis-*O*-(*tert*-butyldimethylsilyl)-2′-deoxyadenosine (20*β*) and It's α-Anomer (20α). A mixture of these two anomers (**20*β***/**20α** = 71/29, calculated by integrating H-2′) was obtained in 72% yield from **17** by the procedure described for the preparation of **18**, except that the reaction was continued for 23 h after finishing addition of Bu_3SnH. HPLC (hexane/EtOAc = 1/2) separation of this mixture gave analytically pure **20*β*** (t_R 19.5 min, solid) and **20α** (t_R 22.8 min, solid).

Physical data of **20*β***: mp 155−158 °C; UV (MeOH) λ_{max} 261 nm (ϵ 13500), λ_{min} 227 nm (ϵ 1500); ^{1}H NMR ($CDCl_3$) δ 0.02, 0.03, and 0.05 (12H, each as s), 0.82 and 0.88 (18H, each as s), 2.53 (1H, dd, J = 5.5 and 13.6 Hz), 2.96−3.08 (3H, m), 3.69 (1H, dd, J = 3.6 and 11.1 Hz), 3.76 (1H, dd, J = 4.0 and 11.1 Hz), 4.06 (1H, ddd, J = 3.6, 4.0, and 4.6 Hz), 4.35 (1H, ddd, J = 4.6, 5.5, and 6.0 Hz), 4.85−4.98 (2H, m), 5.60−5.70 (1H, m), 5.96 (2H, br), 8.15 and 8.32 (2H, each as s); FAB-MS *m*/*z* 520 ($M^+ + H$). Anal. Calcd for $C_{25}H_{45}N_5O_3Si_2$: C, 57.76; H, 8.73; N, 13.47. Found: C, 57.94; H, 9.02; N. 13.18. Physical data of **20α**: mp 161−164 °C; UV (MeOH) λ_{max} 261 nm (ϵ 13600), λ_{min} 228 nm (ϵ 1500); ^{1}H NMR ($CDCl_3$) δ −0.28, −0.11, and 0.10 (12H, each as s), 0.51 and 0.93 (18H, each as s), 2.37 (1H, dd, J = 5.8 and 14.0 Hz), 2.82 (1H, dd, J = 7.2 and 14.0 Hz), 3.09 (1H, dd, J = 7.2 and 14.0 Hz), 3.17 (1H, dd, J = 0.8 and 14.0 Hz), 3.63 (1H, dd, J = 5.6 and 11.0 Hz), 3.75 (1H, dd, J = 3.6 and 11.0 Hz), 4.21 (1H, ddd, J = 1.6, 3.6, and 5.6 Hz), 4.38 (1H, ddd, J = 0.8, 1.6, and 5.8 Hz), 4.93−5.02 (2H, m), 5.49 (2H, br), 5.65−5.76 (1H, m), 8.03 and 8.33 (2H, each as s); FAB-MS *m*/*z* 520 ($M^+ + H$). Anal. Calcd for $C_{25}H_{45}N_5O_3Si_2$: C, 57.76; H, 8.73; N, 13.47. Found: C, 57.76; H, 8.94; N. 13.18.

3′,5′-Bis-*O*-(*tert*-butyldimethylsilyl)-1′-*C*-(2-cyano)ethyl-2′-deoxyuridine (21*β*) and It's α-Anomer (21α). A mixture of **6** (100 mg, 0.18 mmol) and acrylonitrile (60 μL, 0.90 mmol) in benzene (5 mL) was stirred at 80 °C under positive pressure of dry Ar. To this was added a benzene (5 mL) solution of Bu_3SnH (50 μL, 0.18 mmol) and AIBN (12 mg, 0.07 mmol) via a motor-driven syringe over 1 h. The whole reaction mixture was heated with stirring for further 1 h. Evaporation of the solvent followed by column chromatography (hexane/EtOAc = 3/1) gave **21** (75.7 mg, 83%, *β*/α = 74/26, calculated by integrating H-5). HPLC (hexane/EtOAc = 2/1) separation of this mixture gave analytically pure **21*β*** (t_R 14.6 min, solid) and **21α** (t_R 16.8 min, solid). Physical data of **21*β***: mp 78−80 °C; UV (MeOH) λ_{max} 263 nm (ϵ 11000), λ_{min} 232 nm (ϵ 3800); ^{1}H NMR ($CDCl_3$) δ 0.02, 0.03, 0.08, and 0.09 (12H, each as s), 0.85 and 0.90 (18H, each as s), 2.33−2.39 (1H, m), 2.42−2.51 (2H, m), 2.57 (1H, dd, J = 2.2 and 14.5 Hz), 2.65−2.71 (2H, m), 3.63 (1H, dd, J = 3.5 and 11.3 Hz), 3.68 (1H, dd, J = 3.7 and 11.3 Hz), 4.19 (1H, ddd, J = 3.5, 3.7, and 5.7 Hz), 4.31 (1H, ddd, J = 2.2, 2.5, and 5.7 Hz), 5.66 (1H, d, J = 8.4 Hz), 7.90 (1H, d, J = 8.4 Hz), 8.95 (1H, br); FAB-MS *m*/*z* 510 ($M^+ + H$). Anal. Calcd for $C_{24}H_{43}N_3O_5Si_2$: C, 56.55; H, 8.50; N, 8.24. Found: C, 56.73; H, 8.72; N. 8.24. Physical data of **21α**: mp 186−188 °C; UV (MeOH) λ_{max} 263 nm (ϵ 10100), λ_{min} 233 nm (ϵ 3400); ^{1}H NMR ($CDCl_3$) δ −0.01 and 0.09 (12H, each as s), 0.78 and 0.91 (18H, each as s), 2.22−2.44 (4H, m), 2.82−2.87 (1H, m), 2.95 (1H, dd, J = 1.3 and 14.3 Hz), 3.66 (1H, dd, J = 4.5 and 11.2 Hz), 3.72 (1H, dd, J = 3.1 and 11.2 Hz), 4.11 (1H, ddd, J = 1.5, 3.1, and 4.5 Hz), 4.35 (1H, ddd, J = 1.3, 1.4, and 1.5 Hz), 5.70 (1H, d, J = 8.4 Hz), 7.64 (1H, d, J = 8.4 Hz), 8.35 (1H, br); FAB-MS *m*/*z* 510 ($M^+ + H$). Anal. Calcd for $C_{24}H_{43}N_3O_5Si_2$: C, 56.55; H, 8.50; N, 8.24. Found: C, 56.82; H, 8.75; N. 8.44.

3′,5′-Bis-*O*-(*tert*-butyldimethylsilyl)-7-cyano-5,6-dihydro-6,1′-ethano-2′-deoxyuridine (22). This compound (a mixture of two diastereomers, ca. 1:0.4, stereochemistry not known) was obtained in 41% yield as a powder by the procedure described for the preparation of **21**, except that Bu_3SnH(1 equiv)/AIBN (0.4 equiv) was added dropwise over 4 h, and that the reaction mixture was refluxed for 3 h after the addition. FAB-MS *m*/*z* 510 ($M^+ + H$). Anal. Calcd for $C_{24}H_{43}N_3O_5Si_2$: C, 56.55; H, 8.50; N, 8.24. Found: C, 56.68; H, 8.82; N. 8.31.

3′,5′-Bis-*O*-(*tert*-butyldimethylsilyl)-1′-*C*-(2-carbomethoxy)ethyl-2′-deoxyuridine (23*β*) and It's α-Anomer (23α).

A mixture of **6** (100 mg, 0.18 mmol), methyl acrylate (97 μL, 1.08 mmol), and Bu_3SnH (50 μL, 0.18 mmol) in benzene (5 mL) was stirred at 80 °C under positive pressure of dry Ar. To this was added a benzene (5 mL) solution of AIBN (12 mg, 0.07 mmol) via a motor-driven syringe over 1 h. The whole reaction mixture was heated with stirring for further 1 h. Evaporation of the solvent followed by column chromatography (hexane/EtOAc = 3/1−1/1) gave **23** (70 mg, 72%, β/α = 70/30, calculated by integrating H-5). HPLC (hexane/EtOAc = 2/1) separation of this mixture gave analytically pure **23*β*** (t_R 26.4 min, solid) and **23α** (t_R 30.0 min, solid). Physical data of **23*β***: mp 81−83 °C; UV (MeOH) λ_{max} 264 nm (ϵ 10300), λ_{min} 232 nm (ϵ 1400); ^{1}H NMR ($CDCl_3$) δ 0.02, 0.03, 0.06, and 0.08 (12H, each as s), 0.85 and 0.89 (18H, each as s), 2.23−2.30 (1H, m), 2.39−2.46 (2H, m), 2.52 (1H, dd, J = 3.2 and 14.3 Hz), 2.66−2.72 (1H, m), 2.71 (1H, dd, J = 6.1 and 14.3 Hz), 3.61 (1H, dd, J = 3.4 and 11.0 Hz), 3.63 (3H, s), 3.65 (1H, dd, J = 3.8 and 11.0 Hz), 4.05 (1H, ddd, J = 3.4, 3.5, and 3.8 Hz), 4.28 (1H, ddd, J = 3.2, 3.5, and 6.1 Hz), 5.60 (1H, dd, J = 2.0 and 8.5 Hz), 7.89 (1H, d, J = 8.5 Hz), 8.68 (1H, br); FAB-MS m/z 543 ($M^+ + H$). Anal. Calcd for $C_{25}H_{46}N_2O_7Si_2$: C, 55.32; H, 8.54; N, 5.16. Found: C, 55.43; H, 8.75; N. 5.14. Physical data of **23α**: mp 133−136 °C; UV (MeOH) λ_{max} 265 nm (ϵ 10400), λ_{min} 233 nm (ϵ 2500); ^{1}H NMR ($CDCl_3$) δ −0.01 and 0.08 (12H, each as s), 0.78 and 0.91 (18H, each as s), 2.15−2.29 (3H, m), 2.35−2.41 (1H, m), 2.75−2.81 (1H, m), 3.00 (1H, dd, J = 1.6 and 14.5 Hz), 3.56 (1H, dd, J = 5.3 and 11.0 Hz), 3.63 (3H, s), 3.68 (1H, dd, J = 3.5 and 11.0 Hz), 4.01 (1H, ddd, J = 1.9, 3.5, and 5.3 Hz), 4.31 (1H, ddd, J = 1.6, 1.9, and 5.5 Hz), 5.64 (1H, dd, J = 2.5 and 8.4 Hz), 7.64 (1H, d, J = 8.4 Hz), 7.98 (1H, br); FAB-MS m/z 543 ($M^+ + H$). Anal. Calcd for $C_{25}H_{46}N_2O_7Si_2$: C, 55.32; H, 8.54; N, 5.16. Found: C, 55.58; H, 8.70; N. 5.05.

JO0201934