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5-*Exo* versus 6-*Endo* Cyclization of Nucleoside 2-Sila-5-hexenyl Radicals: Reaction of 6-(Bromomethyl)dimethylsilyl 1′,2′-Unsaturated Uridines

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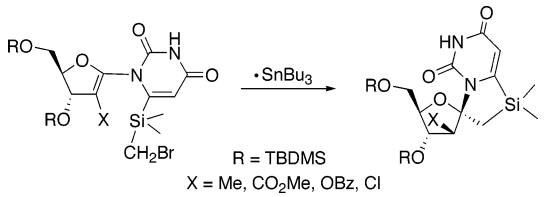
Received September 13, 2004

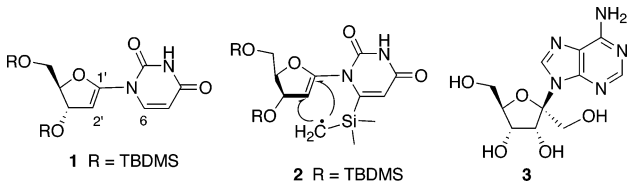


The mode of cyclization of 2-sila-5-hexen-1-yl radicals generated from 6-(bromomethyl)dimethylsilyl-1′,2′-unsaturated uridines was investigated. In contrast to the case of the 2′-unsubstituted 6-silicon-tethered substrate (**4**), which undergoes exclusive 6-*endo*-cyclization, reactions of the 2′-substituted (Me, CO_2Me, OBz, and Cl) derivatives (**14**, **20**, **22**, and **24**) uniformly proceeded in preferential or exclusive 5-*exo*-mode. The Tamao oxidation of the resulting cyclized products was also carried out to synthesize the corresponding 1′-*C*-hydroxymethyl derivatives.

Introduction

It is well appreciated that the 5-*exo*-ring closure of 5-hexenyl radicals is overwhelmingly preferred to the alternative 6-*endo*-cyclization.[1] 5-Hexenyl radicals containing various heteroatoms also follow the same trend[2] with the exception of simple 2-sila and 3-sila counterparts that have been reported to undergo preferential 6-*endo*-cyclization.[3] However, it has also been reported that both 6-*endo* and 5-*exo* pathways are operative in the radical cyclization of allyl alcohols tethered with the (bromomethyl)dimethylsilyl group.[4]

As a part of our continuing studies on the chemistry of 1′,2′-unsaturated uridine,[5,6] 1-(2-deoxy-D-*erythro*-pent-1-enofuranosyl)uracil (**1**), we became interested in the reaction of a nucleoside 2-sila-5-hexenyl radical (**2**) with the expectation that, if its cyclization can be controlled in favor of 5-*exo*-mode, the resulting product would act as a precursor to 1′-*C*-hydroxymethylated nucleosides. Despite the interest generated by the antibacterial and antitumor activities found in the naturally occurring antibiotic angustmycins C (**3**),[7] no systematic study has been executed so far on the structure−activity relationships of this class of nucleosides.[8]



Results and Discussion

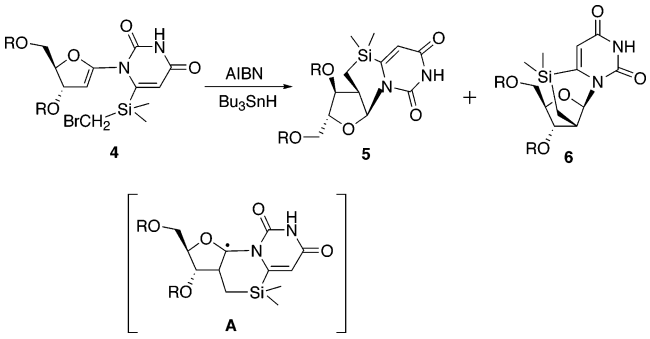
Preparation and Radical Reaction of the 6-(Bromomethyl)dimethylsilyl 1′,2′-Unsaturated Uridine. As

† Showa University.
‡ Kyoto University.

(1) Beckwith, A. L. J.; Schiesser, C. H. *Tetrahedron* **1985**, *41*, 3925.
(2) Beckwith, A. L. J. *Tetrahedron* **1981**, *37*, 3073. Curran, D. P. *Synthesis* **1988**, 417−439.
(3) Wilt, J. W. *Tetrahedron* **1985**, *41*, 3979.
(4) Nishiyama, H.; Kitajima, T.; Matsumoto, M.; Itoh, K. *J. Org. Chem*. **1984**, *49*, 2298.
(5) Itoh, Y.; Haraguchi, K.; Tanaka, H.; Gen, E.; Miyasaka, T. *J. Org. Chem*. **1995**, *60*, 656.
(6) 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.
(7) Buchanan, J. G.; Wightman, R. H. In *Topics in Antibiotic Chemistry*; Sammes, P. G., Ed.; Ellis Horwood Ltd.: Chichester, 1982; Vol. 6, p 231.
(8) For recent reports concerning the synthesis of 1′-branched nucleosides: (a) Kodama, T.; Shuto, S.; Ichikawa, S.; Matsuda, A. *J. Org. Chem*. **2002**, *67*, 7706. (b) Haraguchi, K.; Kubota, Y.; Tanaka, H. *J. Org. Chem*. **2004**, *69*, 1831.

10.1021/jo040260p CCC: $30.25
Published on Web 02/01/2005

SCHEME 1[a]



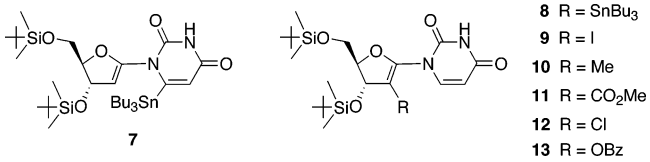
[a] R = TBDMS.

reported previously,[6] the 6-position of **1** can be regioselectively lithiated with LDA. However, when $BrCH_2SiMe_2Cl$ was reacted with the resulting 6-lithiated species of **1**, a large amount of the starting material was recovered, presumably due to susceptibility of the reagent to elimination. The use of LHMDS, which is less basic than LDA, was found to be suitable for the present purpose.[9] Thus, treatment of a mixture of **1** and $BrCH_2SiMe_2Cl$ (4 equiv) with LHMDS (6 equiv) at below −70 °C for 20 min in THF gave the 6-silicon-tethered derivative (**4**) in 87% yield.

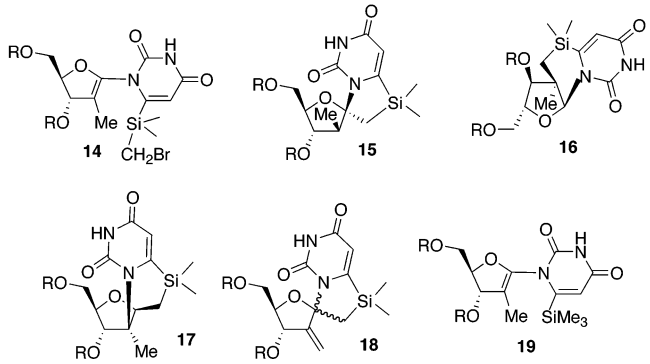
When the radical reaction of **4** was carried out in refluxing benzene by adding a mixture of AIBN (0.2 equiv) and Bu_3SnH (2.0 equiv) via a motor-driven syringe over 1 h at 80 °C (final concentration of the substrate: 0.01 M), only the 6-*endo*-cyclized products **5** (58%) and **6** (32%) were obtained (Scheme 1). Even at a lower temperature of −50 °C (Et_3B/Bu_3SnH in toluene), no 5-*exo*-cyclized product was formed, although a slight increase was observed in the stereoselectivity of the α-face attack (**5**/**6** = 3.1/1, total yield 55%). The regiochemistry of **5** and **6** was apparent from the presence of an anomeric proton resonance (**5**, δ 6.25, $J_{1',2'} = 3.6$ Hz; **6**, δ 5.97, $J_{1',2'} = 4.0$ Hz) that showed a $^3J_{CH}$ correlation to ^{13}C-resonance of the C6 in the HMBC (Heteronuclear Multiple Bond Connectivity) spectrum. The depicted stereochemistry of **5** was unambiguously determined based on an NOE experiment: 7.8% NOE correlation between H-1′ and H-3′.

Although the preferred 6-*endo*-cyclization of a simple 2-sila-hexenyl radical has been rationalized in terms of a longer C−Si bond,[10] we reasoned that, in the present case, the observed exclusive formation of **5** and **6** arises at least in part from stabilization of the anomeric radical **A** by the neighboring furanose ring oxygen. If this is the case, it should be possible to alter the cyclization bias in favor of 5-*exo* by introducing a substituent that stabilizes a 2′-carbon radical.

Cyclization of 2′-Substituted 6-Silicon-Tethered 1′,2′-Unsaturated Uridines. Our recent study showed that the 6-(tributyl)stannylated 1′,2′-unsaturated uridine (**7**), prepared by LDA lithiation of **1** and subsequent reaction with Bu_3SnCl, undergoes an intramolecular anionic migration of the stannyl group to yield the 2′-stannyl derivative **8**.[6] This method enabled us to prepare various types of 2′-substituted derivatives. Thus, iodination of **8** by using iodine gave **9**, which was further transformed to the 2′-methyl (**10**) and the 2′-carbomethoxy (**11**) derivatives through halogen−lithium exchange reaction. Similarly, by reacting **8** with NCS, the 2′-chloro derivative (**12**) was obtained. The 2′-benzoyloxy derivative (**13**) was prepared from 3′,5′-bis-*O*-(*tert*-butyldimethylsilyl)-2′-ketouridine according to the published procedure.[11]



The 2′-methyl-6-silicon-tethered derivative (**14**) was prepared from **10** in 98% yield based on the aforementioned procedure using LHMDS, and its radical reaction was carried out in refluxing benzene in a manner similar to that for **4**. As expected, the 5-*exo*-cyclized product **15** (41%) was formed predominantly over the 6-*endo* product **16** (8%). Additional products formed in this reaction were



the glycosidic bond-rearranged product **17** (29%), the 2′-exomethylene derivative **18** (1%, stereochemistry not known), and the reduced product **19** (4%). When carried out at room temperature (Et_3B/Bu_3SnH/benzene), the amount of **17** (36%) increased at the expense of **15** (26%). The depicted structures of **15**−**17** came from the following ^{1}H NMR observations. Compound **15** showed NOE correlations between H-2′/one of the $SiCH_2$ (11%) and 2′-Me/H-3′ (4%). For **16**, these were observed between H-3′/H-1′ (13%), H-4′/one of the 6-$SiMe_2$ (6%), 2′-Me/H-1′ (4%), and 2′-Me/H-3′ (3%). The regiochemistry of **17** was apparent from the presence of a coupling between H-1′ (double doublet, $J = 2.0$ and 6.4 Hz) and 6-$SiCH_2$, while its stereochemistry was confirmed by the presence of NOE enhancement between H-1′/2′-Me (5%) and H-1′/H-4′ (5%).

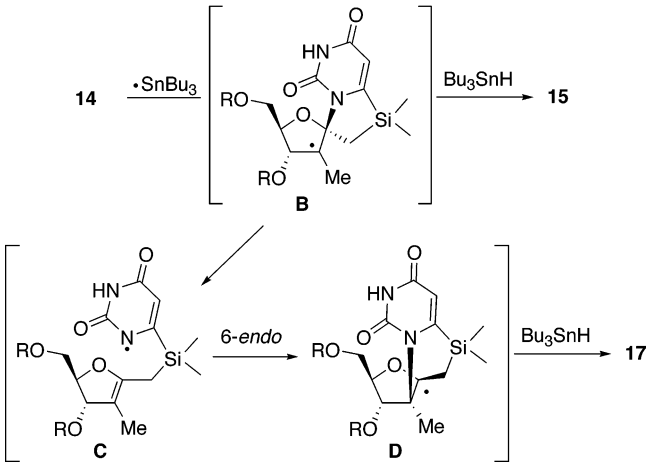
The above results for the reaction of **14**, except for the formation of minor products (**16**, **18**, and **19**), can be rationalized as shown in Scheme 2. The high preference for the C1′-attack of the α-silyl carbon-radial derived from **14** could be due to the formation of an incipient tertiary C2′-radical **B**, although steric hindrance of the 2′-methyl

(9) Use of LHMDS in the C6-silylation of uridine derivatives has recently been reported: Yoshimura, Y.; Kumamoto, H.; Baba A.; Takeda, S.; Tanaka, H. *Org. Lett.* **2004**, *6*, 1793−1795.

(10) Chatgilialoglu, C.; Woynar, H.; Ingold, K. U.; Davies, A. *J. Chem. Soc., Perkin Trans. 2* **1983**, 555.

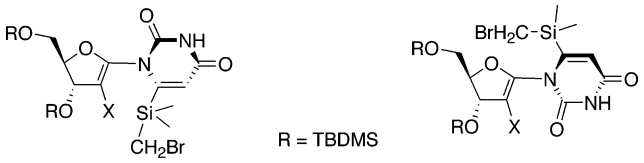
(11) Kodama, T.; Shuto, S.; Nomura, M.; Matsuda, A. *Tetrahedron Lett.* **2000**, *41*, 3643.

SCHEME 2[a]



[a] R = TBDMS.

TABLE 1. Minimized Energies (kcal/mol) of Conformers E−H by Calculation



"down-conformer"
of **4** (X = H): **E**
of **14** (X = Me): **G**

"up-conformer"
of **4** (X = H): **F**
of **14** (X = Me): **H**

compd	conformer energy (kcal/mol)		difference (kcal/mol)
4	**E**	**F**	
	−239.718	−237.793	1.925
14	**G**	**H**	
	−250.769	−246.339	4.430

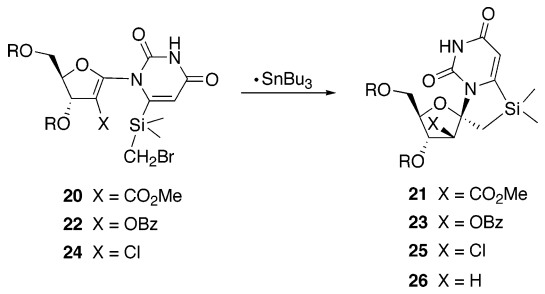
group cannot be ruled out. Also, the observed concurrent formation of **17** may suggest that **B** is not sufficiently stable to react exclusively with Bu_3SnH, and thus, it eliminated uracil-1-yl radical **C** which cyclizes in a 6-*endo* manner to yield a stabilized anomeric radical **D**.

One may question why cyclization of **14** occurred exclusively from the α-face of the furanoid glycal portion leading to **15** and **16**, in comparison with that of **4** where the β-face attack took place to an appreciable extent. As we have no clear explanation for these results, semiempirical molecular orbital calculations[12] of the representative two conformers of **4** (**E** and **F**) and **14** (**G** and **H**) were carried out. Geometries of **4** and **14** were generated from crystallographic coordinates of **1** (see Supporting Information) and optimization was performed with MM2 using CAChe program.The results are summarized in Table 1.

Irrespective of the presence or absence of a substituent at the 2′-position, the "down-conformer" (**E** or **G**) was found to be more stable than the "up-conformer" (**F** or **H**). Also, energy difference between the up and down conformers is significantly larger in the case of **14** (ca. 4.4 kcal/mol) than the case of **4** (ca. 1.9 kcal/mol). These

(12) Semiempirical calculations (PM3) were performed using Spartan (version 3.1) program on a SGI O2 computer.

SCHEME 3[a]



[a] R = TBDMS.

data are in good agreement with the observed stereochemical outcome of the cyclizations of **14** as well as **4**.

To avoid the reaction pathway leading to glycosidic bond-rearrangement, **B** → **C** → **D** (Scheme 2), it is necessary to introduce a substituent that stabilizes the intermediary 2′-carbon radical more efficiently.[13] Since there have been ample precedents that α,β-unsaturated esters undergo radical addition reaction preferentially at the β-position,[14] a carbomethoxy group was selected as a 2′-substituent.

Compound **20** was prepared in 87% yield from **11** and subjected to radical cyclization (Scheme 3). When examined in refluxing benzene, **20** gave the expected 5-*exo*-product **21** in 53% yield together with the recovered **20** (13%), the reduced product (2%), and an unknown product. There was no trace of the 6-*endo* or rearrangement product. The best result was seen in the reaction carried out at room temperature (Et_3B/Bu_3SnH/benzene) to give **21** in 93% along with the reduced product (5%). Reactions of the 2′-benzoyloxy (**22**) and the 2′-chloro (**24**) substrates, carried out under similar conditions, also resulted in exclusive 5-*exo*-cyclization to give **23** (75%) and **25** (66%), respectively. These results suggest that polar effects[15] rather than the steric hindrance of the 2′-substituent are an important determinant for directing this reaction in favor of 5-*exo*-cyclization.

The reaction of **24** deserves a comment. Although **25** was isolated after 1.5 h, it was also possible to obtain the dechlorinated product **26** (69%) simply by further continuing the reaction for 4 days. This compensates for the aforementioned failure of **4** to give the corresponding 5-*exo*-cyclized product.

Oxidative Cleavage of the 5-*Exo*-Cyclized Products. Silicon-tethered molecules are widely used for intramolecular reactions because the tether can be readily removed after the reaction and it offers the scope for facile transformation into other functionalities.[16] The most widely used transformation is the oxidative cleavage of the C−Si bond, the Tamao oxidation,[17] that allows the silicon atom to be converted to a hydroxyl group. There have been several examples of intramolecular radical

(13) For radical stabilization energies of substituents: Brocks, J. J.; Beckhaus, H.-D.; Beckwith, A. L. J.; Rüchardt, C. *J. Org. Chem.* **1998**, *63*, 1935.

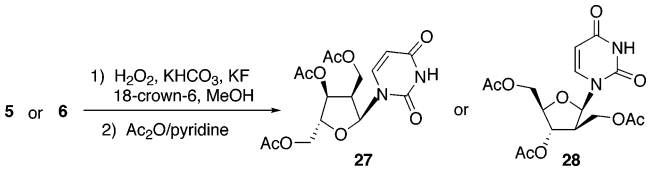
(14) For recent examples: (a) Della, E. W.; Kostakis, C.; Smith, P. A. *Org. Lett.* **1999**, *1*, 363. (b) Kim, K.; Okamoto, S.; Sato, F. *Org. Lett.* **2001**, *3*, 67.

(15) Giese, B. *Angew. Chem., Int. Ed. Engl*. **1983**, *22*, 753.

(16) Bols, M.; Skrydstrup, T. *Chem. Rev*. **1995**, *95*, 1253.

(17) For a review: Tamao, K. In *Advances in Silicon Chemistry*; Larson, G. L., Ed.; JAI Press: London, 1996; Vol. 3, p 1.

SCHEME 4



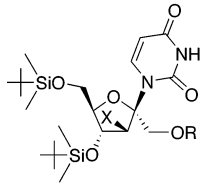
reaction of silicon-tethered nucleosides for the synthesis of their *C*-branched sugar derivatives.[18] In these instances, the silicon-tethers used are uniformly attached to a hydroxyl group of the sugar moiety, therefore the heteroatom needed for the oxidative cleavage of C−Si bond is already attached to the silicon atom. In contrast to this, the present cyclization products have a silicon atom connected to four carbon-substituents.[19]

During our studies on the synthesis of 6-substituted uridines,[20] we experienced that the trimethylsilyl group at the 6-position can be removed simply by reacting with NH_3/MeOH (rt, 1 h), presumably with simultaneous formation of methoxytrimethylsilane. This fact encouraged us to examine the oxidative cleavage of the present cyclized products under these frequently employed basic conditions.

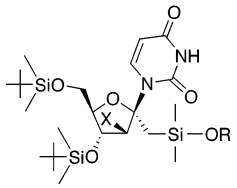
When the 6-*endo*-cyclized product **5** was heated in refluxing MeOH containing $KHCO_3$ (5 equiv), KF (5 equiv), and H_2O_2 (4 equiv), the reaction proceeded very sluggishly and required 3 days for completion.

Although the desired product was isolated in 81% yield as its tri-*O*-acetyl derivative (**27**), we reexamined this reaction. It was found that the addition of 18-crown-6 (5 equiv) to the reaction medium considerably shortened the reaction time. Thus, refluxing for 22 h followed by acetylation gave **27** in 96% yield (Scheme 4). Similarly, **28** was isolated in 66% yield from **6**.

The oxidative cleavage of the 5-*exo*-cyclized products (**21**, **23**, **25**, and **26**)[21] was next examined. Upon treatment under the above-mentioned reaction conditions, the 2′-carbomethoxy derivative **21** was not converted to the expected 1′-hydroxymethyl derivative **29** but instead to a product assumed to be **30**. This product was unstable, giving a more polar compound (**31**?) during silica gel column chromatography. This result suggested that a more electron-withdrawing alkoxy substituent was necessary to increase the Lewis acidity of the silicon atom, rendering the formation of penta- and hexacoordinated silicon intermediates feasible.[17] When the reaction of **21** was carried out in CF_3CH_2OH at rt for 15 h, and it was followed by acetylation, the desired **32** was isolated in 87% yield. Similarly, **33** was obtained in 91% yield from **23**. In the case of the 2′-chloro derivative **25**, the corresponding 1′-hydroxymethyl compound **34** was isolated in 93% yield without acetylation.



29 X = CO_2Me, R = H
32 X = CO_2Me, R = Ac
33 X = OBz, R = Ac
34 X = Cl, R = H
35 X = R = H



30 X = CO_2Me, R = Me
31 X = CO_2Me, R = H

In contrast to these successful examples, the 2′-unsubstituted 5-*exo*-cyclized product **26** gave a considerable amount of uracil under the above oxidation conditions. This may be attributable to the lack of an electron-withdrawing substituent at the 2′-position of **26**, thus rendering the formation of sugar-cation comparatively facile. Compound **35** was, therefore, prepared in 77% yield by the tin-radical mediated dechlorination of **34**.

Conclusion

The mode of cyclization (5-*exo* versus 6-*endo*) of radicals derived from 6-(bromomethyl)dimethylsilyl-1′,2′-unsaturated uridines was studied by changing the substituent at the 2′-position. Compound **4** having no 2′-substituent underwent exclusive 6-*endo*-cyclization consistent with the reported precedent.[10] Although introduction of the 2′-methyl group to **4** changed the cyclization bias in favor of the 5-*exo*-mode, the intermediate 2′-carbon radical is not sufficiently stable. As a result, a considerable extent of glycosidic bond-rearrangement took place in this particular reaction.

Cyclization reactions of other 2′-substituted (CO_2Me, OBz, and Cl) derivatives occurred exclusively in 5-*exo*-mode.

Oxidative cleavage of these cyclized products was also carried out to disclose a new entry to 1′-hydroxymethyl-branched nucleosides. In the oxidation of 5-*exo*-cyclized products, employing CF_3CH_2OH as reaction solvent was critical for an efficient transformation.

Experimental Section

6-(Bromomethyl)dimethylsilyl-1-[3,5-bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-D-*erythro*-pent-1-enofuranosyl]uracil (4). To a THF (60 mL) solution of **1** (2.0 g, 4.4 mmol) and $BrCH_2SiMe_2Cl$ (2.4 mL, 17.6 mmol) was added LHMDS (1.54 M THF solution, 17.1 mL, 26.4 mmol) at below −70 °C under positive pressure of dry Ar. After stirring for 20 min, the reaction mixture was diluted with saturated aqueous NH_4Cl. Extraction with EtOAc followed by column chromatography (hexane/EtOAc = 4/1) gave **4** (2.33 g, 87%) as a foam: UV (MeOH) λ_{max} 267 nm (ϵ 10100), λ_{min} 237 nm (ϵ 4000); ^{1}H NMR ($CDCl_3$) δ 0.08, 0.09, 0.10, and 0.12 (12H, each as s), 0.49 and 0.50 (6H, each as s), 0.90 and 0.91 (18H, each as s), 2.69 and 2.81 (2H, each as d, J = 13.0 Hz), 3.61 (1H, dd, J = 10.4 and 8.4 Hz), 3.81 (1H, dd, J = 10.4 and 6.0 Hz), 4.42 (1H, ddd, J = 8.4, 6.0, and 2.0 Hz), 4.98 (1H, dd, J = 2.8 and 2.0 Hz), 5.20 (1H, d, J = 2.8 Hz), 5.94 (1H, d, J = 2.0 Hz), 8.34 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.5, −5.3, −4.7, −4.6, −3.1 and −3.0, 15.0, 17.9, 18.2, 25.7, 61.6, 75.3, 89.0, 101.4, 112.2, 149.6, 149.7, 156.9, 161.8; FAB-MS *m/z* 605 and 607 ($M^+ + H$). Anal. Calcd for $C_{24}H_{45}BrN_2O_5Si_3 \cdot H_2O$: C, 46.21; H, 7.59; N, 4.49. Found: C, 46.46; H, 7.68; N, 4.74.

(18) (a) Xi, Z.; Agback, P.; Plavec, J.; Sandstrom, A.; Chattopadhyaya, J. *Tetrahedron* **1992**, *48*, 349. (b) Ueno, Y.; Nagasawa, Y.; Sugimoto, I.; Kojima, N.; Kanazaki, M.; Shuto, S.; Matsuda, A. *J. Org. Chem*. **1998**, *63*, 1660. (c) Kodama, T.; Shuto, S.; Nomura, M.; Matsuda, A. *Chem. Eur. J*. **2001**, *7*, 2332.

(19) A phenyldimethylsilyl group attached carbon has been converted to the hydroxyl group in two steps, first with HBF_4 and then with *m*-CPBA/Et_3N: Fleming, I.; Henning, R.; Plaut, H. *J. Chem. Soc., Chem. Commun*. **1984**, 29.

(20) Tanaka, H.; Hayakawa, H.; Miyasaka, T. In *Nucleosides and Nucleotides as Antitumor and Antiviral Agents*; Chu, C. K., Baker, D. C., Eds.; Plenum Press: New York, 1993; p 23.

(21) Due to a small amount of the 2′-methyl-5-*exo*-cyclized product (**15**), the oxidative cleavage of this compounds was not examined.

Radical Cyclization of 4: Formation of the 6-*Endo*-Cyclized Products 5 and 6. To a refluxing benzene (16.5 mL) solution of **4** (200 mg, 0.33 mmol) was added a mixture of AIBN (10.8 mg, 0.066 mmol) and Bu_3SnH (0.18 mL, 0.66 mmol) in benzene (16.5 mL) over 1 h via a motor-driven syringe under positive pressure of dry Ar. The reaction mixture was further refluxed for 20 min and then evaporated. Column chromatography (hexane/EtOAc = 4/1) of the residue gave a mixture of **5** and **6** (157 mg, 90%, **5/6** = 1.8/1.0 calculated by integrating H-1′). Separation of these products was carried out by HPLC (hexane/EtOAc = 3/2) to give analytically pure **5** (t_R = 9.6 min, solid) and **6** (t_R = 11.5 min, foam).

Physical data of **5**: mp 67−75 °C; UV (MeOH) λ_{max} 271 nm (ϵ 10400), λ_{min} 235 nm (ϵ 1700); ^{1}H NMR ($CDCl_3$) δ 0.08, 0.10, and 0.11 (12H, each as s), 0.30 and 0.41 (6H, each as s), 0.68 (1H, dd, J = 9.2 and 15.6 Hz), 0.92 and 0.93 (18H, each as s), 1.26 (1H, dd, J = 15.6 and 5.6 Hz), 2.52−2.66 (1H, m), 3.62−3.68 (2H, m), 3.83 (1H, dd, J = 10.6 and 2.0 Hz), 4.72 (1H, dd, J = 7.4 and 5.8 Hz), 5.83 (1H, d, J = 2.0 Hz), 6.25 (1H, d, J = 3.6 Hz), 8.10 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.6, −5.4, −5.0, −4.8, −2.3, −1.5, 2.0, 18.0, 18.3, 25.7, 25.9, 40.3, 62.1, 71.0, 81.4, 81.9, 109.3, 151.4, 158.3, 161.6; FAB-MS *m/z* 527 (M^+ + H). Anal. Calcd for $C_{24}H_{46}N_2O_5Si_3 \cdot 1/4H_2O$: C, 54.25; H, 8.82; N, 5.27. Found: C, 54.42; H, 9.11; N, 5.28.

Physical data of **6**: UV (MeOH) λ_{max} 270 nm (ϵ 9800), λ_{min} 234 nm (ϵ 1500); ^{1}H NMR ($CDCl_3$) δ 0.06, 0.07, and 0.08 (12H, each as s), 0.30 and 0.35 (6H, each as s), 0.69 (1H, dd, J = 14.8 and 5.0 Hz), 0.89 (18H, s), 1.19 (1H, dd, J = 14.8 and 12.8 Hz), 2.18−2.23 (1H, m), 3.79−3.84 (3H, m), 4.04 (1H, d, J = 2.0 Hz), 5.77 (1H, d, J = 2.4 Hz), 5.97 (1H, d, J = 4.0 Hz), 8.16 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.5, −5.3, −4.7, −4.6, −2.6, −2.5, 7.9, 17.9, 18.5, 25.7, 26.0, 44.0, 62.6, 80.5, 82.5, 85.4, 108.9, 151.8, 157.6, 161.5; FAB-MS *m/z* 527 (M^+ + H). Anal. Calcd for $C_{24}H_{46}N_2O_5Si_3$: C, 54.71; H, 8.80; N, 5.32. Found: C, 54.44; H, 8.93; N, 5.26.

Preparation of Compounds 7−10 and 12. See ref 6.

1-[3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-*C*-carbomethoxy-D-*erythro*-pent-1-enofuranosyl]uracil (11). Under positive pressure of dry Ar, BuLi (1.6 M in hexane, 1.47 mL, 2.35 mmol) was added dropwise to a mixture of **9** (136 mg, 0.234 mmol) and $ClCO_2Me$ (181 μL, 2.34 mmol) in THF (5 mL). After stirring for 20 min, the reaction was quenched by adding saturated aqueous NH_4Cl. Extraction with EtOAc followed by column chromatography (hexane/EtOAc = 6/1) gave **11** (73.3 mg, 61%) as a solid: mp 150−153 °C; UV (MeOH) λ_{max} 245 nm (ϵ 17100), λ_{min} 224 nm (ϵ 14800); ^{1}H NMR ($CDCl_3$) δ 0.09, 012, and 0.15 (12H, each as s), 0.89 (18H, s), 3.68 (1H, dd, J = 11.0 and 6.8 Hz), 3.71 (3H, s), 3.83 (1H, dd, J = 11.0 and 5.2 Hz), 4.51 (1H, ddd, J = 6.8, 5.2, and 2.0 Hz), 5.18 (1H, d, J = 2.0 Hz), 5.79 (1H, dd, J = 8.2 and 2.0 Hz), 7.23 (1H, d, J = 8.2 Hz), 8.33 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.5, −5.4, −4.8, −4.7, 18.0, 18.3, 25.7, 25.8, 51.3, 61.7, 74.3, 90.3, 102.5, 104.3, 142.5, 147.6, 156.6, 162.5, 163.1; FAB-MS *m/z* 513 (M^+ + H). Anal. Calcd for $C_{23}H_{40}N_2O_7Si_2$: C, 53.88; H, 7.86; N, 5.46. Found: C, 53.83; H, 7.90; N, 5.43.

1-[2-*O*-Benzoyl-3,5-bis-*O*-(*tert*-butyldimethylsilyl)-D-*erythro*-pent-1-enofuranosyl]uracil (13). This compound was prepared as a foam in 71% yield from 3′,5′-bis-*O*-(*tert*-butyldimethylsilyl)-2′-ketouridine by the published procedure:[18c] UV (MeOH) λ_{max} 231 nm (ϵ 17700), λ_{min} 212 nm (ϵ 12500), $\lambda_{shoulder}$ 270 nm (ϵ 9500); ^{1}H NMR ($CDCl_3$) δ 0.00, 0.07, and 0.10 (12H, each as s), 0.84 and 0.93 (18H, each as s), 3.81 (1H, dd, J = 11.0 and 6.0 Hz), 3.89 (1H, dd, J = 11.0 and 5.6 Hz), 4.56 (1H, ddd, J = 6.0, 5.6, and 3.0 Hz), 5.27 (1H, d, J = 3.0 Hz), 5.77 (1H, dd, J = 8.0 and 2.4 Hz), 7.40 (1H, d, J = 8.0 Hz), 7.45−7.49 (2H, m), 7.58−7.63 (1H, m), 8.04−8.07 (2H, m), 8.22 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −5.3, −4.7, −4.6, 17.9, 18.4, 25.6, 25.9, 62.4, 74.1, 87.3, 103.0, 123.4, 128.3, 128.6, 130.2, 133.9, 137.0, 141.6, 147.2, 162.3, 163.5; FAB-MS *m/z* 575 (M^+ + H). Anal. Calcd for $C_{28}H_{42}N_2O_7Si_2$: C, 58.51; H 7.37; N, 4.87. Found: C, 58.57; H, 7.46; N, 4.78.

6-(Bromomethyl)dimethylsilyl-1-[3,5-bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-2-*C*-methyl-D-*erythro*-pent-1-enofuranosyl]uracil (14). This compound was obtained as a foam in 98% yield from **10** (100 mg, 0.213 mmol) by the procedure described for the preparation of **4**: UV (MeOH) λ_{max} 265 nm (ϵ 10100), λ_{min} 236 nm (ϵ 4400); ^{1}H NMR ($CDCl_3$) δ 0.08 and 0.13 (12H, each as s), 0.46 and 0.48 (6H, each as s), 0.91 (18H, s), 1.62 (3H, s), 2.69 and 2.77 (2H, each as d, J = 13.2 Hz), 3.58 (1H, dd, J = 10.5 an 8.0 Hz), 3.77 (1H, dd, J = 10.5 and 6.2 Hz), 4.28 (1H, ddd, J = 8.0, 6.2, and 1.6 Hz), 4.72 (1H, d, J = 1.6 Hz), 5.96 (1H, d, J = 2.4 Hz), 8.26 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −5.3, −4.8, −4.4, −3.3, 3.2, 9.5, 14.7, 17.9, 18.5, 25.7, 26.0, 62.0, 78.4, 86.7, 109.3, 112.4, 143.1, 149.5, 157.5, 162.0; FAB-MS *m/z* 619 and 621 (M^+ + H). Anal. Calcd for $C_{25}H_{47}BrN_2O_5Si_3$: C, 48.45; H, 7.64; N, 4.52. Found: C, 48.84; H, 7.80; N, 4.50.

Radical Cyclization of 14: Formation of 15−19. The reaction was carried out by using **14** (75 mg, 0.122 mmol) by the procedure described for the case of **4**. HPLC separation (hexane/EtOAc = 2/1) of the reaction mixture gave **15** (t_R 12.0 min, 27 mg, 41%, foam), **16** (t_R 10.9 min, 4.9 mg, 8%, foam), a mixture of **17** and **19** [t_R 9.8 min, 21.8 mg, **17** (29%) and **19** (4%): the yields were calculated from ^{1}H NMR integration] and **18** (t_R 14.0 min, 0.7 mg, 1%, foam).

Physical data of **15**: UV (MeOH) λ_{max} 252 nm (ϵ 14600), λ_{min} 225 nm (ϵ 5600); ^{1}H NMR ($CDCl_3$) δ 0.02, 0.03, and 0.08 (12H, each as s), 0.40 and 0.42 (6H, each as s), 0.88 and 0.89 (18H, each as s), 1.05 (3H, d, J = 7.2 Hz), 1.55 (1H, d, J = 15.6 Hz), 2.47 (1H, dd, J = 8.2 and 7.2 Hz), 3.80−3.91 (3H, m), 4.42 (1H, dd, J = 8.2 and 7.0 Hz), 5.72 (1H, d, J = 2.4 Hz), 8.16 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.2, −5.0, −4.2, −3.9, −3.3, −2.7, 11.0, 17.7, 18.5, 25.7, 26.0, 29.3, 55.7, 64.4, 77.5, 86.9, 105.7, 106.4, 150.2, 161.5, 163.8; FAB-MS *m/z* 541 (M^+ + H). Anal. Calcd for $C_{25}H_{48}N_2O_5Si_3$: C, 55.51; H, 8.94; N, 5.18. Found: C, 55.82; H, 9.15; N, 5.17.

Physical data of **16**: UV (MeOH) λ_{max} 272 nm (ϵ 10000), λ_{min} 236 nm (ϵ 1800); ^{1}H NMR ($CDCl_3$) δ 0.08, 0.10, 0.11, and 0.12 (12H, each as s), 0.26 (1H, d, J = 16.0 Hz), 0.30 and 0.39 (6H, each as s), 0.93 and 0.94 (18H, each as s), 1.08 (3H, s), 1.51 (1H, d, J = 16.0 Hz), 3.55 (1H, ddd, J = 7.2, 2.4, and 2.0 Hz), 3.67 (1H, dd, J = 11.6 and 2.4 Hz), 3.82 (1H, dd, J = 11.6 and 2.0 Hz), 4.27 (1H, d, J = 7.2 Hz), 5.84 (1H, d, J = 2.0 Hz), 5.94 (1H, s), 7.99 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.6, −5.4, −4.5, −4.3, −1.3, 0.5, 10.3, 18.0, 18.2, 23.7, 25.7, 25.8, 44.8, 62.1, 76.5, 81.3, 86.1, 109.3, 151.6, 158.3, 161.6; FAB-MS *m/z* 541 (M^+ + H). Anal. Calcd for $C_{25}H_{48}N_2O_5Si_3$: C, 55.51; H, 8.94; N, 5.18. Found: C, 55.39; H, 9.19; N, 4.97.

^{1}H NMR and ^{13}C NMR data of **17**: ^{1}H NMR ($CDCl_3$) δ −0.01, 0.11, 0.20, 0.27, and 0.40 (18H, each as s), 0.85 and 0.90 (18H, each as s), 1.02 (1H, dd, J = 2.0 and 15.6 Hz), 1.44 (1H, dd, J = 15.6 and 6.4 Hz), 1.49 (3H, s), 3.27 (1H, dd, J = 10.2 and 7.0 Hz), 3.49 (1H, dd, J = 10.2 and 5.6 Hz), 3.79 (1H, ddd, J = 7.0, 5.6, and 1.2 Hz), 4.36 (1H, dd, J = 6.4 and 2.0 Hz), 4.71 (1H, d, J = 1.2 Hz), 5.75 (1H, d, J = 2.4 Hz), 8.18 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.6, −5.5, −5.4, −5.3, 0.0, 0.2, 8.7, 16.7, 17.9, 18.5, 25.8, 26.0, 63.3, 71.3, 77.4, 80.5, 87.6, 109.2, 151.4, 161.0, 161.4.

Physical data of **18**: UV (MeOH) λ_{max} 263 nm (ϵ 10300), λ_{min} 232 nm (ϵ 3500); ^{1}H NMR ($CDCl_3$) δ −0.01, 0.01, 0.14, and 0.18 (12H, each as s), 0.45 and 0.46 (6H, each as s), 0.86 and 0.94 (18H, each as s), 1.37 and 1.62 (2H, each as d, J = 15.4 Hz), 3.58 (1H, ddd, J = 8.2, 6.0, and 2.4 Hz), 3.76 (1H, dd, J = 11.6 and 6.0 Hz), 3.89 (1H, dd, J = 11.6 and 2.4 Hz), 4.97 (1H, ddd, J = 8.2, 2.4, and 2.2 Hz), 5.09 (1H, d, J = 2.2 Hz), 5.23 (1H, d, J = 2.4 Hz), 5.76 (1H, d, J = 2.4 Hz), 7.75 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −5.3, −4.5, −4.2, −3.5, −2.5, 17.9, 18.3, 25.8, 26.0, 27.4, 62.9, 72.1, 83.4, 100.6, 105.8, 107.8, 149.0, 155.4, 160.6, 163.5; FAB-MS *m/z* 539 (M^+ + H). Anal. Calcd for $C_{25}H_{46}N_2O_5Si_3$: C, 55.72; H, 8.60; N, 5.20. Found: C, 55.69; H, 8.55; N, 4.96.

^{1}H NMR and ^{13}C NMR data of **19**: ^{1}H NMR ($CDCl_3$) δ 0.08, 0.11, and 0.12 (12H, each as s), 0.32 (9H, s), 0.89 and 0.91

(18H, each as s), 1.60 (3H, s), 3.61 (1H, dd, J = 10.6 and 8.4 Hz), 3.78 (1H, dd, J = 10.6 and 6.0 Hz), 4.27 (1H, ddd, J = 8.2, 6.0, and 2.0 Hz), 4.72 (1H, s), 5.91 (1H, d, J = 2.4 Hz), 8.13 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −5.3, −4.3, −1.0, 9.6, 17.9, 18.5, 25.6, 26.0, 62.1, 78.4, 86.6, 108.8, 110.9, 143.4, 149.8, 161.3, 162.2.

6-(Bromomethyl)dimethylsilyl-1-[3,5-bis-*O*-(*tert*-butyldimethylsilyl)-2-*C*-carbomethoxy-2-deoxy-D-*erythro*-pent-1-enofuranosyl]uracil (20). This compound was obtained as a solid (mp 117−120 °C) in 87% yield from **11** (361 mg, 0.703 mmol) by the procedure described for the preparation of **4**: UV (MeOH) λ_{max} 262 nm (ϵ 13200), λ_{min} 221 nm (ϵ 9000); ^{1}H NMR ($CDCl_3$) δ 0.09, 0.14, and 0.18 (12H, each as s), 0.45 and 0.46 (6H, each as s), 0.90 and 0.91 (18H, each as s), 2.66 (2H, s), 3.62 (1H, dd, J = 10.5 and 8.5 Hz), 3.84 (1H, dd, J = 10.5 and 6.0 Hz), 4.52 (1H, ddd, J = 8.5, 6.0, and 1.4 Hz), 5.15 (1H, d, J = 1.4 Hz), 6.00 (1H, d, J = 2.4 Hz), 8.13 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −4.9, −3.5, 14.4, 17.9, 18.4, 25.6, 25.9, 51.5, 60.9, 74.2, 90.3, 107.5, 112.4, 149.2, 156.0, 157.1, 161.6, 163.0; FAB-MS *m/z* 663 and 665 (M^+ + H). Anal. Calcd for $C_{26}H_{47}BrN_2O_7Si_3$: C, 47.04; H, 7.14; N, 4.22. Found: C, 47.07; H, 7.39; N, 4.19.

Radical Cyclization of 20: Formation of 21. To a mixture of **20** (50 mg, 0.076 mmol) and Et_3B (1M THF solution, 30 μL, 0.0304 mmol) in benzene (6.7 mL) was added a benzene (7.6 mL) solution of Bu_3SnH (31 μL, 0.114 mmol) via a motor-driven syringe over 1 h at rt, during which time the same amount of Et_3B was added three times every 15 min. After addition of Bu_3SnH, the reaction mixture was stirred for further 0.5 h. Evaporation of the solvent followed by HPLC separation (hexane/EtOAc = 2/1) gave **21** (t_R 12.4 min, 41 mg, 93%, solid) and the reduced product (t_R 9.2 min, 2.4 mg, 5%, foam). Physical data of **21**: mp 194−195 °C; UV (MeOH) λ_{max} 267 nm (ϵ 10200), λ_{min} 233 nm (ϵ 1700); ^{1}H NMR ($CDCl_3$) δ −0.03, 0.01, 0.11, and 0.14 (12H, each as s), 0.43 and 0.44 (6H, each as s), 0.85 and 0.88 (18H, each as s), 1.69 and 1.77 (2H, each as d, J = 15.2 Hz), 3.39 (1H, d, J = 7.2 Hz), 3.65 (3H, s), 3.71 (1H, dd, J = 11.6 and 7.2 Hz), 3.79 (1H, dd, J = 11.6 and 2.4 Hz), 3.83 (1H, dt, J = 7.2 and 2.4 Hz), 4.92 (1H, t, J = 7.2 Hz), 5.75 (1H, d, J = 2.4 Hz), 7.91 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −5.3, −4.8, −4.5, −3.6, −2.6, 18.0, 18.4, 25.8, 25.9, 30.0, 51.5, 63.5, 64.5, 73.6, 86.2, 102.2, 106.1, 150.1, 160.7, 163.0, 169.5; FAB-MS *m/z* 585 (M^+ + H), 623 (M^+ + K). Anal. Calcd for $C_{26}H_{48}N_2O_7Si_3$: C, 53.39; H, 8.27; N, 4.79. Found: C, 53.39; H, 8.66; N, 4.73.

1-(Bromomethyl)dimethylsilyl-1-[2-*O*-benzoyl-3,5-bis-*O*-(*tert*-butyldimethylsilyl)-D-*erythro*-pent-1-enofuranosyl]uracil (22). This compound was obtained as a foam in 80% yield from **13** (100 mg, 0.174 mmol) by the procedure described for the preparation of **4**: UV (MeOH) λ_{max} 232 nm (ϵ 18200) and 263 nm (ϵ 12800), λ_{min} 218 nm (ϵ 15300) and 250 nm (ϵ 11900); ^{1}H NMR ($CDCl_3$) δ −0.02, 0.09, 0.12 and 0.13 (12H, each as s), 0.57 and 0.58 (6H, each as s), 0.84 and 0.93 (18H, each as s), 2.81 and 2.88 (2H, each as d, J = 13.2 Hz), 3.82 (1H, dd, J = 10.4 and 8.0 Hz), 3.91 (1H, dd, J = 10.4 and 6.4 Hz), 4.41 (1H, ddd, J = 8.0, 6.4 and 1.6 Hz), 5.31 (1H, d, J = 1.6 Hz), 5.98 (1H, s), 7.98 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −4.7, −3.3, −3.2, 14.8, 17.8, 18.5, 25.6, 25.9, 61.7, 76.7, 87.1, 112.7, 127.8, 128.2, 128.7, 130.1, 133.9, 137.7, 148.7, 156.9, 161.4, 163.1; FAB-MS *m/z* 725 and 727 (M^+ + H). Anal. Calcd for $C_{26}H_{48}BrN_2O_7Si_3$: C, 51.29; H, 6.80; N, 3.86. Found: C, 51.41; H, 7.02; N, 3.89.

Radical Cyclization of 22: Formation of 23. This reaction was carried out by using **22** (50 mg, 0.069 mmol) in a similar manner as described for **20**. After addition of Bu_3SnH, the reaction mixture was stirred for 3 h at rt. HPLC separation (hexane/EtOAc = 5/1) of the mixture gave **23** (t_R 14.6 min, 35 mg, 75%, foam) and the reduced product (t_R 11.3 min, 1.5 mg, 3%, foam). Physical data of **23**: UV (MeOH) λ_{max} 232 nm (ϵ 15700) and 265 nm (ϵ 10000), λ_{min} 211 nm (ϵ 10100) and 249 nm (ϵ 6800); ^{1}H NMR ($CDCl_3$) δ −0.04, 0.06, 0.07, and 0.08 (12H, each as s), 0.39 and 0.43 (6H, each as s), 0.84 and 0.90 (18H, each as s), 1.78 and 2.22 (2H, each as d, J = 15.4 Hz), 3.86−4.01 (3H, m), 4.92 (1H, dd, J = 8.0 and 6.2 Hz), 5.46 (1H, d, J = 6.2 Hz), 5.56 (1H, d, J = 2.4 Hz), 7.40−7.44 and 7.55−7.59 (3H, each as m), 7.65 (1H, br), 7.93−7.95 (2H, m); ^{13}C NMR ($CDCl_3$) δ −5.2, −5.1, −4.8, −4.2, −4.1, −3.4, 17.7, 18.5, 25.6, 26.0, 27.6, 64.1, 75.5, 82.6, 89.2, 102.3, 105.4, 128.4, 128.7, 129.6, 133.8, 149.6, 161.2, 163.0, 166.0; FAB-MS *m/z* 647 (M^+ + H). Anal. Calcd for $C_{31}H_{50}N_2O_7Si_3$: C, 57.55; H, 7.79; N, 4.33. Found: C, 57.49; H, 8.08; N, 4.29.

6-(Bromomethyl)dimethylsilyl-1-[3,5-bis-*O*-(*tert*-butyldimethylsilyl)-2-chloro-2-deoxy-D-*erythro*-pent-1-enofuranosyl]uracil (24). This compound was obtained as a powder (mp 127−129 °C) in 89% yield from **12** (330 mg, 0.675 mmol) by the procedure described for the preparation of **4**: UV (MeOH) λ_{max} 263 nm (ϵ 10500), λ_{min} 239 nm (ϵ 6000); ^{1}H NMR ($CDCl_3$) δ 0.09, 0.10, 0.15 and 0.17 (12H, each as s), 0.50 and 0.51 (6H, aech as s), 0.91 and 0.92 (18H, each as s), 2.73 (2H, s), 3.66 (1H, dd, J = 10.6 and 8.2 Hz), 3.84 (1H, dd, J = 10.6 and 6.2 Hz), 4.40 (1H, ddd, J = 8.2, 6.2, and 2.0 Hz), 4.85 (1H, d, J = 2.0 Hz), 5.98 (1H, d, J = 2.4 Hz), 8.20 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −4.7, −4.5, −3.5, −3.4, 1.6, 14.5, 17.6, 18.4, 25.6, 25.9, 61.4, 76.7, 87.7, 108.8, 112.8, 144.9, 148.9, 156.8, 161.7; FAB-MS *m/z* 639 and 641 (M^+ + H). Anal. Calcd for $C_{24}H_{44}BrClN_2O_5Si_3$: C, 45.02; H, 6.93; N, 4.38. Found: C, 45.33; H, 7.02; N, 4.38.

Radical Cyclization of 24: Formation of 25 and 26. This reaction was carried out by using **24** (50 mg, 0.078 mmol) in a similar manner as described for **20**. After finishing addition of Bu_3SnH, the reaction mixture was stirred for 0.5 h at rt. HPLC separation (hexane/EtOAc = 2/1) of the mixture gave **25** (t_R 11.6 min, 28.7 mg, 66%, foam), **26** (t_R 14.2 min, 2.5 mg, 6%, foam), and the reduced product (t_R 8.3 min, 3.7 mg, 8%, foam). When the reaction mixture was stirred for 4 days, **26** was isolated in 69% together with **25** (trace amount) and the reduced product (7%).

Physical data of **25**: UV (MeOH) λ_{max} 262 nm (ϵ 10100), λ_{min} 229 nm (ϵ 1900); ^{1}H NMR ($CDCl_3$) δ 0.05, 0.11, and 0.15 (12H, each as s), 0.43 and 0.44 (6H, each as s), 0.88 and 0.90 (18H, each as s), 1.70 and 1.78 (2H, each as d, J = 15.6 Hz), 3.81 (1H, dd, J = 11.2 and 1.6 Hz), 3.91 (1H, ddd, J = 8.3, 8.1, and 1.6 Hz), 4.01 (1H, dd, J = 11.2 and 8.3 Hz), 4.23 (1H, d, J = 8.0 Hz), 4.77 (1H, dd, J = 8.1 and 8.0 Hz), 5.73 (1H, d, J = 2.4 Hz), 8.47 (1H,br); ^{13}C NMR ($CDCl_3$) δ −5.2, −5.1, −4.6, −3.8, −3.1, −3.0, 17.8, 18.5, 25.7, 26.0, 29.0, 64.0, 73.1, 78.5, 84.8, 103.4, 105.9, 149.7, 160.3, 163.4; FAB-MS *m/z* 561 (M^+ + H). Anal. Calcd for $C_{24}H_{45}ClN_2O_5Si_3$: C, 51.35; H, 8.08; N, 4.99. Found: C, 51.59; H, 8.31; N, 4.99.

Physical data of **26**: UV (MeOH) λ_{max} 258 nm (ϵ 7400), λ_{min} 232 nm (ϵ 2400); ^{1}H NMR ($CDCl_3$) δ 0.00, 0.01, 0.08, and 0.09 (12H, each as s), 0.38 and 0.44 (6H, each as s), 0.87 and 0.90 (18H, each as s), 1.42 and 1.72 (2H, each as d, J = 15.2 Hz), 2.05 (1H, dd, J = 13.3 Hz), 3.51 (1H, dd, J = 13.3 and 7.7 Hz), 3.67 (1H, dd, J = 12.0 and 7.6 Hz), 3.77−3.82 (2H, m), 4.59 (1H, dd, J = 7.7, and 6.0 Hz), 5.74 (1H, d, J = 2.4 Hz), 8.05 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −5.2, −4.8, −3.8, −3.5, −2.7, 17.9, 18.4, 25.8, 25.9, 29.2, 47.1, 63.4, 72.4, 87.1, 103.7, 105.9, 149.7, 161.2, 163.2; FAB-MS *m/z* 527 (M^+ + H). Anal. Calcd for $C_{24}H_{46}N_2O_5Si_3$: C, 54.25; H, 8.82; N, 5.27. Found: C, 54.40; H, 8.72; N, 5.12.

1-(2-*C*-Acetoxymethyl-3,5-di-*O*-acetyl-2-deoxy-α-D-ribofuranosyl)uracil (27). A mixture of **5** (100 mg, 0.19 mmol), 30% aqueous H_2O_2 (73 μL, 0.76 mmol), 18-crown-6 (251 mg, 0.95 mmol), $KHCO_3$ (81 mg, 0.95 mmol), and KF (55 mg, 0.95 mmol) in MeOH (3 mL) was stirred at refluxing temperature for 22 h. The reaction mixture was evaporated and dried under reduced pressure. To a pyridine (3 mL) solution of the resulting residue was added Ac_2O (0.45 mL, 4.75 mmol) and the mixture was stirred at rt overnight. Evaporation of the solvent followed by column chromatography (EtOAc) gave **27** (70 mg, 90%) as a foam: UV (MeOH) λ_{max} 261 nm (ϵ 12000), λ_{min} 231 nm (ϵ 2600); ^{1}H NMR ($CDCl_3$) δ 2.02, 2.10, and 2.14 (9H, each as s), 3.23−3.30 (1H, m), 4.07−4.21 (4H, m), 4.58 (1H, dt, J = 4.8

and 1.0 Hz), 5.40 (1H, dd, J = 6.0 and 1.0 Hz), 5.76 (1H, d, J = 8.2 Hz), 6.47 (1H, d, J = 7.2 Hz), 7.41 (1H, d, J = 8.2 Hz), 8.50 (1H, br); ^{13}C NMR ($CDCl_3$) δ 20.7, 20.8, 20.9, 45.2, 57.6, 63.5, 73.6, 84.5, 86.8, 102.0, 139.8, 150.5, 163.1, 169.5, 170.4; FAB-MS m/z 385 (M^+ + H). Anal. Calcd for $C_{16}H_{20}N_2O_9 \cdot 1/5H_2O$: C, 49.54; H, 5.30; N, 7.22. Found: C, 49.47; H, 5.16; N, 6.86.

1-(2-*C*-Acetoxymethyl-3,5-di-*O*-acetyl-2-deoxy-*β*-D-arabinofuranosyl)uracil (28). This compound was prepared as a foam in 66% yield from **6** (100 mg, 0.19 mmol) by the procedure described for the preparation of **27**. The reaction was continued for 16 h at the refluxing temperature of MeOH: UV (MeOH) λ_{max} 262 nm (ϵ 9400), λ_{min} 230 nm (ϵ 2100); ^{1}H NMR ($CDCl_3$) δ 2.00, 2.13 and 2.14 (9H, each as s), 3.05−3.09 (1H, m), 4.04 (1H, dd, J = 12.0 and 3.6 Hz), 4.15 (1H, dd J = 12.0 and 5.2 Hz), 4.18 (1H, ddd, J = 5.2, 4.4 and 3.2 Hz), 4.40 (1H, dd, J = 12.2 and 4.4 Hz), 4.43 (1H, dd, J = 12.2 and 3.2 Hz), 5.10 (1H, dd, J = 5.2 and 4.8 Hz), 5.75 (1H, d, J = 8.0 Hz), 6.17 (1H d, J = 6.4 Hz), 7.55 (1H, d, J = 8.0 Hz), 8.77 (1H, br); ^{13}C NMR ($CDCl_3$) δ 20.5, 20.7, 21.0, 46.6, 59.6, 62.6, 73.6, 80.6, 85.5, 101.9, 139.6, 150.2, 163.1, 170.1, 170.2, 170.3; FAB-MS m/z 385 (M^+ + H). Anal. Calcd for $C_{16}H_{20}N_2O_9 \cdot 1/5H_2O$: C, 49.54; H, 5.30; N, 7.22. Found: C, 49.42; H, 5.18; N, 6.90.

1-[1-*C*-Acetoxymethyl-3,5-bis-*O*-(*tert*-butyldimethylsilyl)-2-*C*-carbomethoxy-2-deoxy-*β*-D-arabinofuranosyl]uracil (32). To a solution of **21** (16.7 mg, 0.029 mmol) in CF_3CH_2OH (1.5 mL) were added $KHCO_3$ (14.5 mg, 0.145 mmol), 18-crown-6 (38 mg, 0.145 mmol), KF (8.4 mg, 0.145 mmol), and 30% aqueous H_2O_2 (13.1 μL, 0.116 mmol) at −20 °C. The reaction mixture was stirred for 15 h at rt, evaporated, and partially purified by Florisil column chromatography (hexane/EtOAc = 2/1). The resulting crude product was treated overnight with Ac_2O (16.4 μL, 0.17 mmol) in pyridine (2 mL). Florisil column chromatography (hexane/EtOAc = 10/1) of the acetylation mixture gave **32** (14.8 mg, 87%) as a foam: UV (MeOH) λ_{max} 261 nm (ϵ 10600), λ_{min} 230 nm (ϵ 1900); ^{1}H NMR ($CDCl_3$) δ 0.03, 0.07, 0.09, and 0.10 (12H, each as s), 0.87 and 0.92 (18H, each as s), 2.05 (3H, s), 3.36 (1H, d, J = 6.2 Hz), 3.76 (1H, dd, J = 11.2 and 3.2 Hz), 3.89 (1H, dd, J = 11.2 and 4.4 Hz), 3.93−3.97 (1H, m), 4.53 (1H, t, J = 6.2 Hz), 4.71 and 4.77 (2H, each as d, J = 10.4 Hz), 5.65 (1H, dd, J = 8.4 and 2.4 Hz), 8.00 (1H, d, J = 8.4 Hz) 8.36 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −5.0, −4.9, 0.0, 17.8, 18.3, 20.7, 25.5, 25.9, 52.4, 58.3, 60.3, 64.8, 74.1, 85.8, 95.1, 101.0, 141.2, 150.0, 162.9, 169.9, 170.0; FAB-MS m/z 587 (M^+ + H), 625 (M^+ + K). Anal. Calcd for $C_{26}H_{46}N_2O_9Si_2$: C, 53.22; H, 7.90; N, 4.77. Found: C, 53.62; H, 8.05; N, 4.72.

1-[1-*C*-Acetoxymethyl-3,5-bis-*O*-(*tert*-butyldimethylsilyl)-2-*O*-benzoyl-*β*-D-arabinofuranosyl]uracil (33). This compound was prepared in 91% yield as a foam from **23** (13.8 mg, 0.021 mmol) by the procedure described for the preparation of **32**, except that the oxidative cleavage was performed at 0 °C for 15 h. Acetylation mixture was purified by Florisil column chromatography (hexane/EtOAc = 5/1): UV (MeOH) λ_{max} 233 nm (ϵ 16500) and 262 nm (ϵ 10400), λ_{min} 212 nm (ϵ 9300) and 249 nm (ϵ 8300); ^{1}H NMR ($CDCl_3$) δ −0.06, −0.03, 0.14, and 0.23 (12H, each as s), 0.80 and 0.94 (18H, each as s), 2.06 (3H, s), 3.59 (1H, dd, J = 7.6 Hz), 3.78 (1H, dd, J = 10.4 and 5.8 Hz), 4.24 (1H, ddd, J = 7.6, 5.8, and 1.6 Hz), 4.33 (1H, t, J = 1.6 Hz), 4.74 and 4.96 (2H, each as d, J = 12.0 Hz), 5.61 (1H, d, J = 1.6 Hz), 5.74 (1H, dd, J = 8.4 and 2.4 Hz), 7.38−7.42 (2H, m), 7.54−7.57 (1H, m), 7.78−7.80 (2H, m), 7.91 (1H, d, J = 8.4 Hz), 8.12 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.6, −5.5, −5.2, −4.8, 17.8, 18.2, 20.6, 25.6, 25.7, 62.2, 63.0, 76.8, 79.9, 88.2, 97.3, 100.7, 128.7, 129.3, 133.7, 128.8, 141.2, 149.2, 163.0, 163.9, 170.0; FAB-MS m/z 687 (M^+ + K). Anal. Calcd for $C_{31}H_{48}N_2O_9Si_2$: C, 57.38; H, 7.46; N, 4.32. Found: C, 57.24; H, 7.55; N, 4.30.

1-[3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-chloro-2-deoxyl-1-*C*-hydroxymethyl-*β*-D-arabinofuranosyl]uracil (34). This compound was prepared in 93% yield as a foam from **25** (23.5 mg, 0.041 mmol) by the procedure described for the preparation of **32**. After stirring at rt for 3 h, the oxidation mixture was quenched by adding saturated aqueous $Na_2S_2O_3$. Extraction with EtOAc followed by HPLC purification (hexane/EtOAc = 1/2) gave **34** (t_R = 12.3 min, 20.2 mg, 93%) as a foam: UV (MeOH) λ_{max} 261 nm (ϵ 12700), λ_{min} 230 nm (ϵ 3300); ^{1}H NMR ($CDCl_3$) δ 0.10, 0.13, and 0.16 (12H, each as s), 0.91 and 0.92 (18H, each as s), 3.14 (1H, br), 3.82 (1H, dd, J = 10.7 and 6.6 Hz), 3.87 (1H, dd, J = 10.7 and 4.8 Hz), 4.07 (1H, ddd, J = 6.6, 4.8, and 3.2 Hz), 4.19 (1H, s), 4.20 (1H, d, J = 3.2 Hz), 4.47 (1H, dd, J = 3.2 and 2.0 Hz), 4.57 (1H, d, J = 2.0 Hz), 5.67 (1H, dd, J = 8.3 and 1.8 Hz), 7.84 (1H, d, J = 8.3 Hz), 8.71 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.4, −5.0, 4.7, 17.8, 18.4, 25.6, 25.9, 61.8, 63.1, 65.7, 79.8, 86.7, 99.9, 100.5, 142.5, 149.8, 165.0; FAB-MS m/z 559 (M^+ + K). Anal. Calcd for $C_{22}H_{41}ClN_2O_6Si_2$: C, 50.70; H, 7.93; N, 5.37. Found: C, 50.75; H, 8.17; N, 5.23.

1-[3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxyl-*β*-D-psicofuranosyl]uracil (35). A mixture of **34** (38 mg, 0.073 mmol), Et_3B (1 M THF solution, 146 μL, 0.146 mmol), and Bu_3SnH (39 μL, 0.146 mmol) in benzene (3.0 mL) was stirred at rt. After 2 h, the same amount of Et_3B was added to the reaction mixture, and stirring was continued for further 1 h. Evaporation of the solvents followed by HPLC purification (hexane/EtOAc = 1/2) gave **35** (t_R = 9.8 min, 27 mg, 77%) as a foam: UV (MeOH) λ_{max} 263 nm (ϵ 12700), λ_{min} 234 nm (ϵ 7100); ^{1}H NMR ($CDCl_3$) δ 0.03, 0.04, 0.09, and 0.10 (12H, each as s), 0.86 and 0.90 (18H, each as s), 2.55 (1H, dd, J = 14.8 and 2.4 Hz), 2.62 (1H, dd, J = 8.0 and 5.0 Hz), 2.69 (1H, dd, J = 14.8 and 5.6 Hz), 3.61−3.68 (2H, m), 3.92 (1H, dd, J = 11.6 and 8.0 Hz), 3.97 (1H, dd, J = 11.6 and 5.0 Hz), 4.15 (1H, dd, J = 5.8 and 4.0 Hz), 4.34 (1H, dt, J = 5.6 and 2.4 Hz), 5.62 (1H, d, J = 8.4 Hz), 7.90 (1H, d, J = 8.4 Hz), 8.31 (1H, br); ^{13}C NMR ($CDCl_3$) δ −5.7, −5.6, −5.0, −4.8, 17.5, 18.2, 25.6, 25.7, 44.1, 62.4, 65.9, 72.5, 89.6, 99.9, 100.2, 142.1, 150.1, 164.4; FAB-MS m/z 487 (M^+ + H). Anal. Calcd for$C_{22}H_{42}N_2O_6Si_2$: C, 54.29; H, 8.70; N, 5.76. Found: C, 54.44; H, 9.03; N, 5.62.

Acknowledgment. This study was supported by Grants-in-Aid (KAKENHI) from JSPS (Japan Society for the Promotion of Science): No. 15790075 to H.K. and No. 15590020 to H.T. We are also grateful to Ms. K. Shiobara and Y. Odanaka (Center for Instrumental Analysis, Showa University) for technical assistance with NMR, MS, and elemental analyses.

Supporting Information Available: X-ray crystallographic coordinates for compound **1** (CIF) and General Experimental Section. This material is available free of charge via the Internet at http://pubs.acs.org.

JO040260P