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Stereoselective Synthesis of the β-Anomer of 4′-Thionucleosides Based on Electrophilic Glycosidation to 4-Thiofuranoid Glycals

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Three types of 4-thiofuranoid glycal with different 3,5-*O*-silyl protecting groups were prepared and their electrophilic glycosidation was investigated. The 3,5-bis-*O*-(*tert*-butyldimethylsilyl)-4-thiofuranoid glycal (**5**) was obtained through mesylation of 2-deoxy-4-thio-D-*erythro*-pentofuranose (**4**) and subsequent base-promoted elimination, while thermal elimination of sulfoxide derivatives was suitable for the preparation of 3,5-*O*-(tetraisopropyldisiloxane-1,3-diyl) (**9**) and 3,5-*O*-(di-*tert*-butylsilylene) (**11**) 4-thioglycals. The glycosidation reactions of these 4-thioglycals were carried out, in the presence of either PhSeCl or NIS, by using silylated derivatives of uracil, thymine, cytosine, and N^6-benzoyladenine. Among the three 4-thioglycals, **11** was found to be an excellent glycosyl donor, forming the desired β-anomer exclusively irrespective of the nucleobase employed.

Introduction

Nucleoside analogues constitute an important class of biologically active compounds, especially as antiviral and anticancer agents.[1] Recently, 4′-thionucleosides, in which the furanose ring oxygen is replaced by a sulfur atom, have been synthesized extensively due to the discovery of their promising biological activities.[2] Since the first report by Reist et al. in 1964,[3] the synthesis of 4′-thionucleosides has mostly been carried out based on the Vorbrüggen-type condensation between an appropriate 4-thiopentofuranose and a silylated nucleobase.[4] Although the Pummerer-type thioglycosidation[5] is also available as an alternative, a serious drawback commonly seen in these methods is the lack of the desired β-stereoselectivity. For example, in the synthesis of 2′-deoxy-4′-thionucleosides, the α-anomer was obtained as a major product in many cases. Surprisingly, even in the synthesis of the 4′-thioribofuranosides, where neighboring group participation by the 2-*O*-acyl group can be expected, the β-anomer is formed only in a slight excess. This stereochemical outcome limits the accessibility to a variety of 4′-thionucleosides that are necessary for the efficient study of structure−activity relationships in medicinal chemistry.[6]

Glycals have been used as versatile glycosyl donors for the synthesis of carbohydrate derivatives.[7] Some nucleosides have been prepared with a high β-selectivity by electrophilic addition to glycals.[8] However, such an

(1) Review, see: (a) *Nucleosides And Nucleotides as Antitumor And Antiviral Agents*; Chu, C. K., Baker, D. C., Ed.; Plenum Press: New York, 1993. (b) Ichikawa, E.; Katoh, K. *J. Synth. Org. Chem., Jpn.* **2001**. *59*, 331−345.

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(6) Stereoselective synthesis of 4′-thionucleosides has recently appeared. (a) Inguaggiato, G.; Jasamai, M.; Smith, J. E.; Slater, M.; Simons, C. *Nucleosides Nucleotides*, **1999**, *18*, 457−467. (b) Naka, T.; Nishizono, N.; Minakawa, N.; Matsuda, A. *Tetrahedron Lett.* **1999**, *40*, 6297−6300. (c) Naka, T.; Minakawa, N.; Abe, H.; Kaga, D.; Matsuda, A. *J. Am. Chem. Soc.* **2000**, *122*, 7233−7243. (d) Miller. J. A.; Pugh, A. W.; Ullah, G. M. *Tetrahedron Lett.* **2000**, *41*, 3265−3268.

(7) For a review of synthetic chemistry of glycals, see: Collins, P. M.; Ferrier, R. J. *Monosaccharides, Their Chemistry and Their Roles in Natural Products*; John Wiley & Sons: Chichester, U.K., 1995; pp 317−326.

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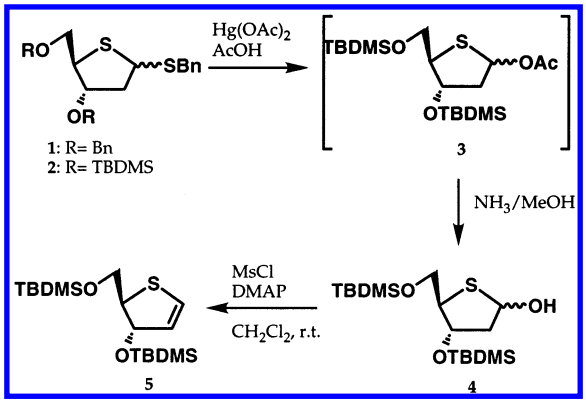
approach has not been investigated for the synthesis of 4′-thionucleosides. These facts led us to carry out the first β-face-selective electrophilic glycosidation of 4-thiofuranoid glycals.[9] In this article, the synthesis of the β-anomer of 2′-deoxy-4′-thiopyrimidine nucleosides as well as their further transformation into the ribo and arabino analogues are described. Also reported here is an extension of the above chemistry to the synthesis of adenine nucleosides.

Results and Discussion

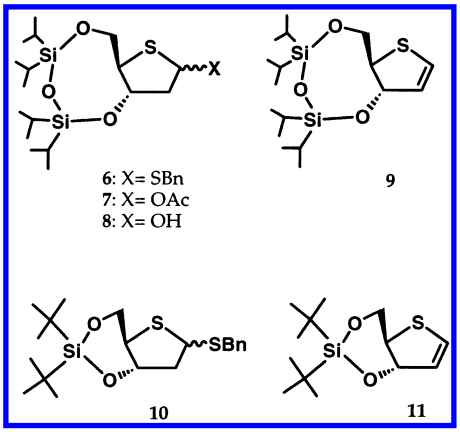
Preparation of Three Types of Silyl-Protected 4-Thiofuranoid Glycals. Among a number of methodologies for the preparation of glycals,[10] we envisioned that the elimination reaction of protected 1-*O*-mesyl-pentofuranose reported by Townsend et al.[11] would be relevant because the corresponding 4-thio derivative can be prepared from benzyl 3,5-di-*O*-benzyl-1,4-dithio-D-*erythro*-pentofuranoside (**1**), which is available from 2-deoxy-D-ribose in seven steps in good yield.[12]

As shown in Scheme 1, selective debenzylation of **1** with BBr_3/CH_2Cl_2 at below −70 °C followed by conventional silylation led to **2** in 68% yield. Subsequent acetolysis of **2** with $Hg(OAc)_2$/AcOH gave **3**, which was then deacetylated with NH_3/MeOH to afford **4** in 92% yield in two steps. Compound **4** was found to undergo β-elimination upon treatment with $MsCl/CH_2Cl_2$ at room temperature in the presence of DMAP. Thus, the 3,5-bis-*O*-(*tert*-butyldimethylsilyl) derivative **5** was obtained in 80% yield from **4**.

SCHEME 1



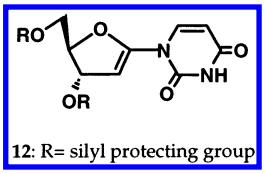
Preparation of the 3,5-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl) derivative **9** was first carried out by following the synthetic route shown in Scheme 1. The protected dithiacetal **6** was converted to **7** (88%) and then to **8** (95%). Presumably due to conformational rigidity, β-elimination reaction of the mesylated **8** in the presence of DMAP was very sluggish at room temperature. In CH_2Cl_2 under reflux, a complex mixture of products resulted. It was found that the use of the more basic Et_3N in refluxing CH_2Cl_2 gave **9** in 67% yield. This reaction sequence is not applicable to the preparation of the 3,5-*O*-(di-*tert*-butylsilylene) derivative **11**, since acetolysis of the corresponding dithiacetal **10** gave a mixture of unidentified products. We therefore decided to examine an alternative method that can be used for the preparation of both **9** and **11**.



It would be reasonable to assume that the observed high yield-formation of **3** and **7** is a likely consequence of selective coordination of the electrophilic $Hg(OAc)_2$ to the sulfur atom of the 1-benzylthio group. Also, there is precedent that the *exo*-cyclic sulfur atom of ethyl α- and β-1,5-dithioglucopyranosides is more susceptible to *m*-CPBA oxidation than the *endo*-cyclic one.[13] These facts encouraged us to carry out regioselective oxidation of the 1-benzylthio group of **6** and **10**, which could be followed by thermal elimination of α-toluenesulfenic acid.

Compound **6** was treated with *m*-CPBA (1.6 equiv)/CH_2Cl_2 at −70 °C to give a mixture of oxidation products, which showed a rather complex ^1H NMR spectrum. Upon heating this mixture in refluxing xylene in the presence of *i*-Pr_2NEt, **9** was obtained in 59% yield. When the same reaction sequence was applied to **10**, the desired **11** was obtained in 57% yield.

Electrophilic Glycosidation to 4-Thiofuranoid Glycals 5, 9, and 11. During our studies on the chemistry of 1′,2′-unsaturated uridine (**12**), we have seen that



the face-selectivity of the approach to the 1′,2′-double bond by the incoming electrophile can be controlled by changing the silyl protecting group of the 3′- and 5′-hydroxyl groups.[14] That is, approach to the α-face using NBS increased in the order of 3′,5′-*O*-(di-*tert*-butylsilylene): DTBS > 3′,5′-*O*-(1,1,3,3-tetraisopropyldisilox-

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(13) Yuasa, H.; Kamata, Y.; Hashimoto, H. *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 868−869.

ane-1,3-diyl): TIPDS > 3′,5′-bis-*O*-(*tert*-butyldimethylsilyl): TBDMS. This trend was also seen in the present electrophilic glycosidation to 4-thiofuranoid glycals (**5**, **9**, and **11**), the results of which are summarized in Scheme 2 and in Table 1.

SCHEME 2

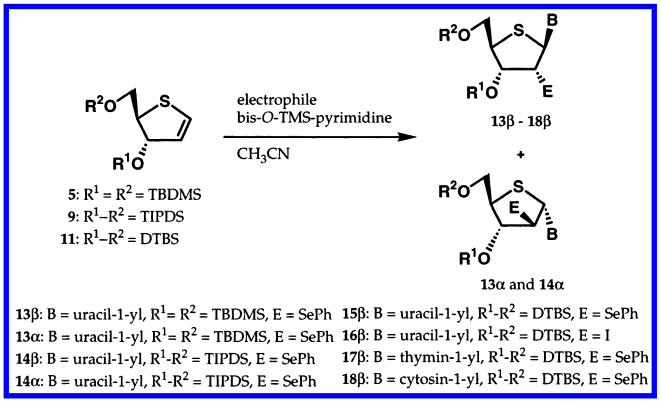
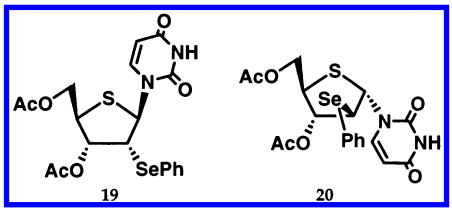


TABLE 1. Electrophilic Glycosidation to 4-Thiofuranoid Glycals 5, 9, and 11

entry	glycal	electrophile (equiv)	B	products (isolated yield)	β:α[a,b]
1	**5**	PhSeCl (1.5)	uracil-1-yl	**13*β*** and **13α** (88%)	4:1
2	**9**	PhSeCl (1.5)	uracil-1-yl	**14*β*** and **14α** (87%)	18:1
3	**11**	PhSeCl (1.5)	uracil-1-yl	**15*β*** (88%)	-
4	**11**	NIS (1.5)	uracil-1-yl	**16*β*** (73%)	-
5	**11**	PhSeCl (1.5)	thymin-1-yl	**17*β*** (62%)	-
6	**11**	PhSeCl (1.5)	cytosin-1-yl	**18*β*** (85%)	-

[a] The ratio was determined by ^{1}H NMR spectroscopy. [b] In entries 3−6. The α-isomer could not be detected by ^{1}H NMR spectroscopy of the glycosylated product.

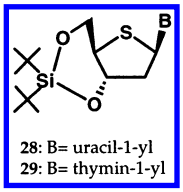
When PhSeCl (1.5 equiv) was reacted with the TBDMS-4-thioglycal **5** in the presence of silylated uracil (1.5 equiv) in CH_3CN at 0 °C for 1 h, the reaction went to completion to give a mixture of **13***β* and **13**α in 88% yield with a ratio of 4:1 (entry 1). As shown in entry 2, stereoselectivity was improved by using the TIPDS-4-thioglycal **9** (**14***β*:**14**α = 18:1). Furthermore, the reaction of the DTBS derivative **11** gave the desired *β*-anomer (**15***β*) as the sole product in 88% yield (entry 3). The depicted stereochemistry of these 4′-thionucleosides came from the following results. Treatment of **13***β*, **14***β*, and **15***β* separately with Bu_4NF in the presence of Ac_2O in THF gave the identical crystalline 3′,5′-di-*O*-acetyl derivative (**19**). The X-ray crystallographic analysis of **19** confirmed its anomeric *β*-configuration as well as the 2-deoxy-2-(phenylselenenyl)-4-thioribofuranosyl structure.[9a] Likewise, **13**α and **14**α were converted to **20**. The NOE experiment of **20** showed a correlation between H-1′/H-3′ (4.4%), H-6/H-4′ (2%), and H-6/H-2′ (10%).



This glycosidation method also works well by using NIS as an electrophile (entry 4). It seems likely that use of the DTBS-4-thioglycal (**11**) as a glycosyl donor uniformly leads to the exclusive formation of *β*-anomer, irrespective of nucleobase employed, as shown in entries 5 and 6 by the preparation of thymine and cytosine derivatives (**17***β* and **18***β*). This was also seen in the reaction of silylated N^6-benzoyladenine (Scheme 3). In this particular case, however, three isomeric *β*-glycosides **21**−**23** were formed. Regiochemistry of these compounds was determined after converting to the respective 2′-deoxy derivative (**24**−**26**) by treatment with Bu_3SnH/Et_3B in benzene at room temperature. The N^7-substituted structure of **25** was confirmed by X-ray crystallographic analysis.[15]

That **26** is assumed to be the N^1-glycosidation product came from the presence of NOE correlation between H-1′ and phenyl protons of the N^6-benzoyl group. Compound **24** was further treated with NH_3/MeOH to give **27**, the UV absorption maximum (λ_{max} 260 nm in MeOH) of which suggested the N^9-substituted structure.[16a,b] Although we do not have a satisfactory explanation, it was interesting to see that the use of monosilylated N^6-benzoyladenine was crucial for preferential glycosidation at the 9-position (**21**, 51%; **22**, 2%; **23**, 2%). When the bis-silylated nucleobase was employed, N^1-glycosidation become the major reaction pathway (**21**, 6%; **22**, 13%; **23**, 30%).

The present glycosidation method has the advantage that the introduced 2′-phenylseleno and 2′-iodo functionalities can be used for further transformations. This was briefly exemplified by the preparation of the 2′-deoxyribofuranosyl, ribofuranosyl, and arabinofuranosyl analogues of 4′-thiopyrimidine nucleosides. As described above in the case of adenine derivatives, Et_3B-initiated radical reactions of **15***β*, **16***β*, and **17***β*, when carried out at room temperature, led to the respective 2′-deoxy derivatives (**28** and **29**) in 61−69% yields without formation of furanose ring-opened byproduct.[1k]



Compound **16***β* also serves as a precursor for the preparation of ribo and arabino analogues (Scheme 4). Thus, treatment of **16***β* with DBN in CH_3CN gave the O^2,2′-cyclonucleoside **30** (95%), which was desilylated with Bu_4NF/THF to yield **31** (97%). When reacted with LiOBz,[17] **31** gave a mixture of *O*-benzoylated products as a result of benzoyl group migration. After debenzoylation of this mixture, the resulting ribo analogue **32** was isolated as its tris-*O*-triethylsilyl derivative **33** in 52% yield. A conventional alkaline treatment of **31** gave the arabinofuranosyl analogue **34** in 88% yield.

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(15) For X-ray crystallographic data of **25**; see Supporting Information.

(16) (a) Yoshimura, Y.; Watanabe, M.; Satoh, H.; Ashida, N.; Ijichi, K.; Sakata, S.; Machida, H.; Matsuda, A. *J. Med. Chem.* **1997**, *40*, 2177−2183. (b) In NOE experiment, correlation between H-8/H-3′ (4.5%) was observed.

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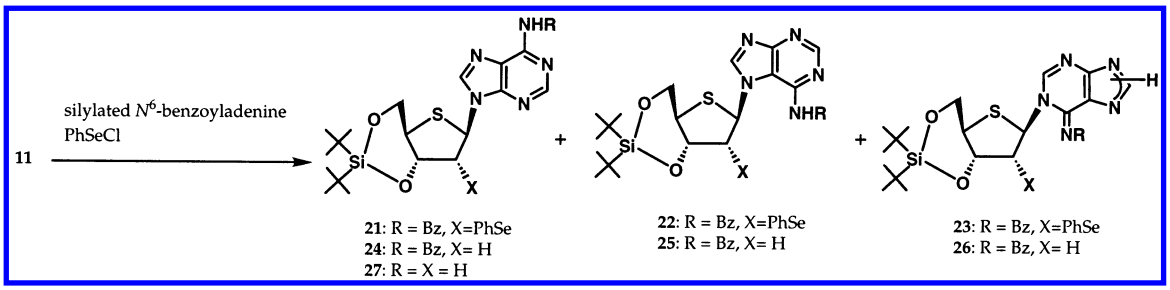
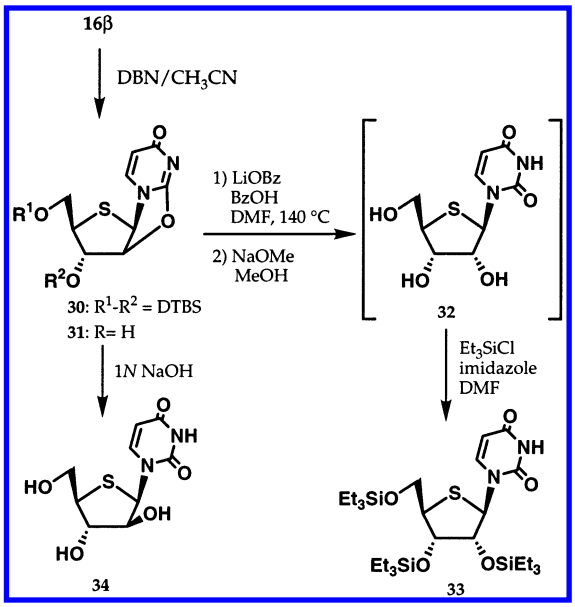
SCHEME 3



SCHEME 4



Conclusion

A novel method has been developed for 4′-thionucleosides based on electrophilic glycosidation to 4-thiofuranoid glycals. Among the glycals used, the DTBS-4-thioglycal **11** was found to give the β-anomer exclusively, irrespective of nucleobase employed. We are currently studying factors governing this stereochemical outcome. An additional attraction of this method is the ready accessibility of the corresponding 2′-deoxy, 2′-ribo, and 2′-arabino analogues by simple manipulation of the resulting glycosidation products. This efficient preparation of sugar-modified 4′-thionucleosides enables a more expedient study of structure−activity relationships.

Experimental Section

Melting points are uncorrected. NMR was measured at 400 or 500 MHz. Chemical shifts are reported relative to Me_4Si for ^1H NMR. Mass spectra (MS) were taken in FAB mode (*m*-nitrobenzyl alcohol as a matrix). Column chromatography was carried out on silica gel (silica gel 60). Thin-layer chromatography (TLC) was performed on silica gel (precoated silica gel plate F_{254}). HPLC was carried out with a shim-pack PREP-SIL(H)·KIT column (2 × 25 cm).

Benzyl 3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-1,4-dithio-D-*erythro*-pentofuranoside (2). To a CH_2Cl_2 (35 mL) solution of BBr_3 (1.0 M in CH_2Cl_2) (4.1 mL, 42.9 mmol) was added a CH_2Cl_2 (35 mL) solution of **1** (7.50 g, 17.2 mmol) at −70 °C under Ar atmosphere, and the reaction mixture was stirred for 1 h.. The reaction was quenched by adding pyridine (25 mL) and dry MeOH (25 mL). After being stirred for 0.5 h at − 70 °C, the reaction mixture was gradually warmed to room temperature and further stirred for 0.5 h. The reaction mixture was evaporated to dryness. Silica gel column chromatography (2% MeOH in $CHCl_3$) of the residue gave the diol. The diol was silylated by TBDMSCl (5.18 g, 34.4 mmol) and imidazole (2.93 g, 43.0 mmol) in DMF (25 mL) at room temperature. The reaction mixture was partitioned between AcOEt/H_2O. Silica gel column chromatography (hexane/ethyl acetate = 100/1) of the organic layer gave **2** (5.46 g, 68%, a mixture (8/1) of diastereomers) as a syrup.

^1H NMR ($CDCl_3$) major-isomer δ 0.03, 0.05, 0.06 (12H, each as s), 0.86, 0.89 (18H, each as s), 1.91 (1H, ddd, J = 4.0, J = 9.2 and $J_{2a,2b}$ = 13.0 Hz), 2.11 (1H, ddd, J = 3.7, J = 5.8 and $J_{2a,2b}$ = 13.0 Hz), 3.30 (1H, ddd, $J_{3,4}$ = 2.4, $J_{4,5b}$ = 5.5 and $J_{4,5a}$ = 9.2 Hz), 3.48 (1H, dd, $J_{4.5a}$ = 9.2 and $J_{5a,5b}$ = 10.7 Hz), 3.61 (1H, dd, $J_{4,5b}$ = 5.5 and $J_{5a,5b}$ = 10.7 Hz), 3.83 (2H, s), 4.48−4.51 (2H, m), 7.22−7.26, 7.29−7.34 (5H, each as m). minor-isomer δ 1.99 (1H, dt, $J_{1,2a}$ = $J_{2a,3}$ = 7.0 and $J_{2a,2b}$ = 13.0 Hz), 2.37 (1H, ddd, $J_{2b,3}$ = 5.2, $J_{1,2b}$ = 7.0 and $J_{2a,2b}$ = 13.0 Hz), 3.66 (1H, dd, $J_{4,5b}$ = 5.8 and $J_{5a,5b}$ = 10.1 Hz), 4.22 (1H, dt, $J_{1,3}$ = $J_{2b,3}$ = 5.2 and $J_{2a,3}$ = 7.0 Hz), 4.27 (1H, t, $J_{1,2a}$ = $J_{1,2b}$ = 7.0 Hz), 7.22−7.26, 7.27−7.34 (5H, each as m); FAB-MS *m*/*z* 485 (M^+ + H), 427 (M^+ − ^{t}Bu). Anal. Calcd for $C_{24}H_{44}O_2S_2Si_2$: C, 59.45; H, 9.15. Found: C, 59.70; H, 9.25.

3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-1,4-dithio-D-*erythro*-pentofuranose (4). To a stirred solution of **2** (931 mg, 1.92 mmol) in AcOH (17.1 mL, 300 mL) was added $Hg(OAc)_2$ (1.41 g, 4.42 mmol), and the mixture was stirred at room temperature for 2 h. The reaction mixture was diluted with $CHCl_3$ and washed successively with H_2O, sat. $NaHCO_3$, and 5% NaCN. Silica gel column chromatography (hexane/ethyl acetate = 100/1) of the organic layer gave **3**. Compound **3** was treated with methanolic ammonia (60 mL), and the solution was kept at room temperature overnight. The reaction mixture was evaporated and the residue was chromatographed on a silica gel (hexane/ethyl acetate = 100/1) to give **4** (670 mg, 92%, a mixture (4/1) of epimers) as a syrup.

^1H NMR ($CDCl_3$+H_2O) major-isomer δ 0.03, 0.05, 0.16 (12H, each as s), 0.89, 0.91 (18H, each as s), 2.03 (1H, ddd, $J_{2a,3}$ = 3.1, $J_{1,2a}$ = 4.6 and $J_{2a,2b}$ = 13.6 Hz), 2.30 (1H, dd, $J_{2b,3}$ = 0.9 and $J_{2a,2b}$ = 13.6 Hz), 3.16 (1H, t, $J_{4.5a}$ = $J_{5a,5b}$ = 10.7 Hz), 3.50 (1H, dd, $J_{4,5b}$ = 4.9 and $J_{5a,5b}$ = 10.7 Hz), 3.65 (1H, dd, $J_{3,4}$ = 2.4, $J_{4,5a}$ = 4.9 and $J_{4,5b}$ = 10.7 Hz), 4.77 (1H, dd, $J_{2b,3}$ = 0.9 and $J_{2a,3}$ = 3.1 Hz), 5.46 (1H, d, $J_{1,2a}$ = 4.6 Hz). minor-isomer ($CDCl_3$+H_2O). δ 0.07, 0.08, 0.09 (12H, each as s), 0.88, 0.91 (18H, each as s), 2.15 (1H, ddd, $J_{1,2a}$ = 4.6, $J_{2a,3}$ = 7.9 and $J_{2a,2b}$ = 12.8 Hz), 2.27 (1H, ddd, $J_{2b,3}$ = 5.2, $J_{1,2b}$ = 3.1 and $J_{2a,2b}$ = 12.8 Hz), 3.66−3.39 (1H, m), 3.73 (1H, dd, $J_{4,5a}$ = 4.6 and $J_{5a,5b}$ = 10.4 Hz), 3.80 (1H, dd, $J_{4,5b}$ = 4.9 and $J_{5a,5b}$ = 10.4 Hz), 4.54 (1H, dt, $J_{3,4}$ = $J_{2b,3}$ = 5.2 and $J_{2a,3}$ = 7.9 Hz), 5.38 (1H, dd, $J_{1,2a}$ = 4.6 and $J_{1,2b}$ = 3.1 Hz); FAB-MS *m*/*z* 361 (M^+ − OH), 321 (M^+ − ^{t}Bu). Anal. Calcd for $C_{17}H_{38}O_3SSi_2$:C, 53.91; H, 10.11. Found: C, 53.85; H, 10.30.

1,4-Anhydro-3,5-bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-4-thio-D-*erythro*-pent-1-enitol (5). To a stirred solution of **4** (149 mg, 0.39 mmol) and DMAP (240 mg, 1.96 mmol) in CH_2Cl_2 (4 mL) was added MsCl (0.12 mL, 1.57 mmol) at 0 °C under Ar atmosphere. After being stirred overnight, the reaction mixture was partitioned between $CHCl_3$ and sat.

$NaHCO_3$. Silica gel column chromatography of the organic layer gave **5** (113 mg, 80%) as a syrup. UV (MeOH) λ_{max} 236 nm (ϵ 3900); ^{1}H NMR ($CDCl_3$) δ 0.06, 0.07, 0.10 and 0.11 (12H, each as s), 0.89 and 0.90 (18H, each as s), 3.45 (1H, dd, $J_{4,5a}$ = 9.2 and $J_{5a,5b}$ = 10.1 Hz), 3.59 (1H, ddd, $J_{3,4}$ = 2.2, $J_{4,5a}$ = 9.2 and $J_{4,5b}$ = 6.5 Hz), 3.69 (1H, dd, $J_{4,5b}$ = 6.5 and $J_{5a,5b}$ = 10.1 Hz), 5.02 (1H, dd, $J_{3,4}$ = 2.2 and $J_{2,3}$ = 3.1 Hz), 5.58 (1H, dd, $J_{2,3}$ = 3.1 and $J_{1,2}$ = 5.8 Hz), 6.33 (1H, d, $J_{1,2}$ = 5.8 Hz); FAB-MS *m*/*z* 303 (M^+ − ^{t}Bu). Anal. Calcd for $C_{17}H_{36}O_2SSi_2$: C, 56.61; H, 10.06. Found: C, 53.88; H, 9.95.

Benzyl 2-Deoxy-1,4-dithio-3,5-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-D-*erythro*-pentofuranoside (6). The reaction was carried out according to the procedure described for the preparation of **2** starting from **1** (6.22 g, 14.2 mmol), BBr_3(1.0 M in CH_2Cl_2, 3.77 mL, 39.9 mmol), 1,3-dichloro-1,1,3,3-tetraisopropyldisiloxane (6.83 mL, 21.4 mmol) and imidazole (3.88 g, 57.0 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 100/1) of the crude mixture gave **6** (4.76 g, 70%, a mixture (9/1)of diastereomers) as a syrup.

^{1}H NMR ($CDCl_3$) major-isomer δ 0.95−1.07 (28H, m), 2.24 (1H, ddd, $J_{1,2a}$ = 1.2, $J_{2a,3}$ = 5.5 and $J_{2a,2b}$ = 12.8 Hz), 2.36 (1H, ddd, $J_{1,2b}$ = 6.4, $J_{2b,3}$ = 10.7 and $J_{2a,2b}$ = 12.8 Hz), 3.30 (1H, ddd, $J_{3,4}$ = 7.8, $J_{4,5b}$ = 3.1 and $J_{4,5a}$ = 5.6 Hz), 3.80 (2H, s), 3.90 (1H, dd, $J_{4.5a}$ = 5.6 and $J_{5a,5b}$ = 12.1 Hz), 4.02 (1H, dd, $J_{4,5b}$ = 3.1 and $J_{5a,5b}$ = 12.1 Hz), 4.14 (1H, dd, $J_{1,2a}$ = 1.2 and $J_{1,2b}$ = 6.4 Hz), 4.69 (1H, ddd, $J_{2a,3}$ = 5.5, $J_{2b,3}$ = 10.7 and $J_{3,4}$ = 7.8 Hz), 7.21−7.25, 7.27−7.32 (5H, each as m). minor-isomer (selected data). δ 0.93−1.12 (28H, m), 2.01 (1H, ddd, $J_{1,2a}$ = 9.5, $J_{2a,3}$ = 10.4 and $J_{2a,2b}$ = 12.5 Hz), 2.52 (1H, dt, $J_{2b,3}$ = $J_{1,2b}$ = 7.0 and $J_{2a,2b}$ = 12.5 Hz), 3.40−3.43 (1H, m), 4.07 (1H, dd, $J_{4,5b}$ = 3.1 and $J_{5a,5b}$ = 12.5 Hz), 4.22 (1H, dd, $J_{1,2a}$ = 9.5 and $J_{1,2b}$ = 7.0 Hz), 4.22−4.27 (1H, m), 7.23−7.32 (5H, m); FAB-MS *m*/*z* 537 (M^+ + K), 455 (M^+ − ^{i}Pr). Anal. Calcd for $C_{24}H_{42}O_3S_2Si_2$: C, 57.78; H, 8.49. Found: C, 57.83; H, 8.64.

1-*O*-Acetyl-2-deoxy-3,5-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-4-thio-D-*erythro*-pentofuranose (7). The reaction was carried out according to the procedure described for the preparation of **3** starting from **6** (2.36 g, 4.74 mmol), AcOH (42.3 mL, 739 mL) and $Hg(OAc)_2$ (3.17 g, 9.95 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 100/1) of the crude product gave **7** (1.82 g, 88%, a mixture (1.1/1)of epimers) as a syrup.

^{1}H NMR ($CDCl_3$) major-isomer δ 1.04−1.09 (28H, m), 2.02 (3H, s), 2.27 (1H, ddd, $J_{1,2a}$ = 4.8, $J_{2a,3}$ = 11.6 and $J_{2a,2b}$ = 13.0 Hz), 2.38 (1H, dd, $J_{2b,3}$ = 5.2 and $J_{2a,2b}$ = 13.0 Hz), 3.25 (1H, ddd, $J_{3,4}$ = 8.6, $J_{4,5b}$ = 2.8 and $J_{4,5a}$ = 4.0 Hz), 3.84 (1H, dd, $J_{4.5a}$ = 4.0 and $J_{5a,5b}$ = 12.4 Hz), 4.06 (1H, dd, $J_{4,5b}$ = 2.8 and $J_{5a,5b}$ = 12.4 Hz), 4.63 (1H, ddd, $J_{2a,3}$ = 11.6, $J_{2b,3}$ = 5.2 and $J_{3,4}$ = 8.6 Hz), 5.87 (1H, d, $J_{1,2a}$ = 4.8 Hz). minor-isomer δ major-isomer δ 1.04−1.09 (28H, m), 2.06 (3H, s), 2.17 (1H, ddd, $J_{1,2a}$ = 6.0, $J_{2a,3}$ = 10.4 and $J_{2a,2b}$ = 13.2 Hz), 2.69 (1H, dt, $J_{1,2b}$ = $J_{2b,3}$ = 6.8 and $J_{2a,2b}$ = 13.2 Hz), 3.40 (1H, dt, $J_{3,4}$ = 8.8 and $J_{4,5b}$ = $J_{4,5a}$ = 3.1 Hz), 3.84 (1H, dd, $J_{4.5a}$ = 3.1 and $J_{5a,5b}$ = 12.5 Hz), 4.08 (1H, dd, $J_{4,5b}$ = 2.8 and $J_{5a,5b}$ = 12.4 Hz), 4.27 (1H, ddd, $J_{2a,3}$ = 10.4 and $J_{2b,3}$ = 6.8 and $J_{3,4}$ = 8.8 Hz), 5.99 (1H, dd, $J_{1,2a}$ = 6.0 and $J_{1,2b}$ = 6.8 Hz); FAB-MS *m*/*z* 473 (M^+ + K), 375 (M^+ − OAc). Anal. Calcd for $C_{19}H_{38}O_5SSi_2$: C, 52.49; H, 8.81. Found: C, 52.55; H, 9.19.

2-Deoxy-3,5-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-4-thio-D-*erythro*-pentofuranose (8). The reaction was carried out according to the procedure described for the preparation of **3** starting from **7** (197 mg, 0.45 mmol) and methanolic ammonia (20 mL). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 20/1) of the crude product gave **8** (170 mg, 95%, a mixture (2.8/1) of epimers) as a syrup. ^{1}H NMR ($CDCl_3$+D_2O) major-isomer δ 1.03−1.13 (28H, m), 2.19 (1H, ddd, $J_{1,2a}$ = 4.6, $J_{2a,3}$ = 12.6 and $J_{2a,2b}$ = 11.8 Hz), 2.40 (1H, dd, $J_{2b,3}$ = 5.5 and $J_{2a,2b}$ = 11,8 Hz), 3.31 (1H, ddd, $J_{3,4}$ = 8.0, $J_{4,5b}$ = 3.1 and $J_{4,5a}$ = 5.2 Hz), 3.88 (1H, dd, $J_{4.5a}$ = 5.2 and $J_{5a,5b}$ = 12.2 Hz), 4.07 (1H, dd, $J_{4,5b}$ = 3.1 and $J_{5a,5b}$ = 12.2 Hz), 4.67−4.72 (1H, m), 5.27 (1H, d, $J_{1,2a}$ = 4.6 Hz). δ minor isomer ($CDCl_3$+D_2O) δ 1.03−1.13 (28H, m), 2.30 (1H, ddd, $J_{1,2a}$ = 3.6, $J_{2a,3}$ = 5.2 and $J_{2a,2b}$ = 11.0 Hz), 2.38−2.45 (1H, m), 3.63 (1H, dd, $J_{4.5a}$ = 8.4 and $J_{5a,5b}$ = 11.6 Hz), 3.77 (1H, dt, $J_{3,4}$ = $J_{4,5b}$ = 4.0 and $J_{4,5a}$ = 8.4 Hz), 4.00 (1H, dd, $J_{4,5b}$ = 4.0 and $J_{5a,5b}$ = 11.6 Hz), 4.67−4.72 (1H, m), 5.48 (1H, dd, $J_{1,2a}$ = 3.6 and $J_{1,2b}$ = 5.0 Hz); FAB-MS *m*/*z* 393 (M^+ + H), 375 (M^+ − OH). Anal. Calcd for $C_{17}H_{36}O_4SSi_2$: C, 51.99; H, 9.24. Found: C, 52.05; H, 9.39.

1,4-Anhydro-2-deoxy-3,5-*O*-(1,1,3,3-tetraisopropyldisiloxan-1,3-diyl)-4-thio-D-*erythro*-pent-1-enitol (9). To a stirred solution of **8** (1.25 g, 3.17 mmol) and Et_3N (3.03 mL, 22.2 mmol) in CH_2Cl_2 (20 mL) was added MsCl (1.23 mL, 15.9 mmol) at 0 °C under Ar atmosphere, and the mixture was stirred at 45 °C for 4 h. The reaction mixture was partitioned between $CHCl_3$ and sat. $NaHCO_3$. Silica gel column chromatography (hexane/ethyl acetate = 400/1) of the organic layer gave **9**(800 mg, 67%) as a syrup. UV (MeOH) λ_{max} 237 nm (ϵ 4500); ^{1}H NMR ($CDCl_3$) δ 1.04−1.11 (28H, m), 3.79 (1H, t, $J_{4,5a}$ = $J_{5a,5b}$ = 11.3 Hz), 3.85−3.89 (1H, m), 4.09 (1H, dd, $J_{4,5b}$ = 4.0 and $J_{5a,5b}$ = 11.3 Hz), 5.42−5.44 (1H, m), 5.56 (1H, dd, $J_{2,3}$ = 2.5 and $J_{1,2}$ = 5.8 Hz), 6.22 (1H, dd, $J_{1,2}$ = 5.8 and $J_{1,3}$ = 1.6 Hz); FAB-MS *m*/*z* 375 (M^+ + H). Anal. Calcd for $C_{17}H_{34}O_3SSi_2$: C, 54.49; H, 9.15. Found: C, 54.62; H, 9.13.

Benzyl 2-Deoxy-3,5-*O*-(di-*tert*-butylsilylene)-1,4-dithio-D-*erythro*-pentofuranoside (10). The reaction was carried out according to the procedure described for the preparation of **2** starting from **1** (888 mg, 2.03 mmol), BBr_3 (1.0 M CH_2Cl_2 solution) (0.48 mL, 5.09 mmol), di-*tert*-butylsilyl bis(trifluoromethanesulfonate) (0.74 mL, 2.03 mmol), and imidazole (291 mg, 4.27 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 70/1) of the crude product gave **10** (625 mg, 77%, a mixture (6.6/1)of diastereomers) as a syrup. UV (MeOH) λ_{sh} 266 nm (ϵ 4200), λ_{sh} 259 nm (ϵ 2700); ^{1}H NMR ($CDCl_3$) major-isomer δ 0.98 and 1.07 (18H, each as s), 2.14 (1H, ddd, $J_{1,2a}$ = 7.6, $J_{2a,3}$ = 11.6 and $J_{2a,2b}$ = 12.7 Hz), 2.04 (1H, dd, $J_{2b,3}$ = 15,2 and $J_{2a,2b}$ = 12.7 Hz), 3.30 (1H, ddd, $J_{3,4}$ = 9.5, $J_{4,5b}$ = 4.6 and $J_{4,5a}$ = 11.0 Hz), 3.77 and 3.81 (2H, each as s), 4.02 (1H, dd, $J_{4.5a}$ = 11.0 and $J_{5a,5b}$ = 10.1 Hz), 4.18 (1H, d, $J_{1,2a}$ = 7.6 Hz), 4.24 (1H, dd, $J_{4,5b}$ = 4.6 and $J_{5a,5b}$ = 10.1 Hz), 4.46 (1H, ddd, $J_{2a,3}$ = 11.6, $J_{2b,3}$ = 5.2 and $J_{3,4}$ = 9.5 Hz), 7.23−7.27, 7.28−7.33 (5H, each as m); minor-isomer δ 0.99 and 1.03 (18H, each as s), 1.84 (1H, ddd, $J_{1,2a}$ = 9.8, $J_{2a,3}$ = 11.0 and $J_{2a,2b}$ = 12.4 Hz), 2.65 (1H, m), 3.49 (1H, dd, $J_{3,4}$ = 9.5, $J_{4,5a}$ = 11.3, and $J_{4,5b}$ = 4.6), 3.77 and 3.81 (2H, each as d, J_{gem} = 13.8 Hz), 3.91 (1H, dd, $J_{4,5a}$ = 11.3 and $J_{5a,5b}$ = 10.1 Hz), 4.10 (1H, ddd, $J_{2a,3}$ = 11.0, $J_{2b,3}$ = 6.1, and $J_{3,4}$ = 9.5 Hz), 4.23−4.28 (1H, m), 7.23−7.33 (5H, m); FAB-MS *m*/*z* 396 (M^+). Anal. Calcd for $C_{20}H_{32}O_2S_2Si$: C, 60.56; H, 8.13. Found: C, 60.68; H, 8.18.

1,4-Anhydro-2-deoxy-3,5-*O*-(di-*tert*-butylsilylene)-4-thio-D-*erythro*-pent-1-enitol (11) (prepared from 5). Tetrabutylammonium fluoride (177 mg, 0.68 mmol) was added to a solution of **5** (111 mg, 0.31 mmol) in THF (5 mL) at 0 °C under Ar atmosphere, and the mixture was stirred for 0.5 h. The reaction mixture was evaporated to dryness, and the residue was chromatographed on a silica gel (1% MeOH in CH_2Cl_2) to give the diol, which was silylated with di-*tert*-butylsilyl bis(trifluoromethanesulfonate) (95 μL, 0.26 mmol) and (dimethylamino)pyridine (63.4 mg, 0.52 mmol) in DMF (4 mL) at 0 °C under Ar atmosphere overnight. The reaction mixture was diluted with ehtyl acetate and washed with sat. $NaHCO_3$ and H_2O. Silica gel column chromatography (hexane/ethyl acetate = 100/1) of the organic layer gave **11** (30.9 mg, 49%) as a solid. mp 68−69 °C; UV (MeOH) λ_{max} 242 nm (ϵ 4100), λ_{min} 220 nm (ϵ 980); ^{1}H NMR ($CDCl_3$) δ 1.03 and 1.06 (18H, each as s), 3.81−3.87 (1H, m) 4,29 (1H, t, $J_{4,5a}$ = $J_{5a,5b}$ = 10.1 Hz), 4.33 (1H, dd, $J_{4,5b}$ = 0.6 and $J_{5a,5b}$ = 10.1 Hz), 5.11 (1H, ddd, $J_{1,3}$ = 2.5, $J_{2,3}$ = 2.7 and $J_{3,4}$ = 12.2 Hz), 5.86 (1H, dd, $J_{2,3}$ = 2.7 and $J_{1,2}$ = 6.1 Hz), 6.19 (1H, dd, $J_{1,3}$ = 2.5 and $J_{1,2}$ = 6.1 Hz); FAB-MS *m*/*z* 273 (M^+ + H), 215 (M^+ − ^{t}Bu). Anal. Calcd for $C_{13}H_{24}O_2SSi$: C, 57.30; H, 8.88. Found: C, 57.54; H, 9.10.

Synthesis of TIPDS-glycal (9) and DTBS-glycal (11) via Sulfoxide Elimination. 1,4-Anhydro-2-deoxy-3,5-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-4-thio-D-*erythro*-pent-1-enitol (9). To a stirred solution of **6** (2.32 g, 4.65 mmol) in CH_2Cl_2 (30 mL) was added a CH_2Cl_2 (15 mL) solution of m-CPBA (712 mg, 5.58 mmol) at −70 °C, and the mixture was stirred for 2.5 h. The reaction mixture was neutralized with Et_3N and partitioned between $CHCl_3/H_2O$. Silica gel column chromatography (hexane/ethyl acetate = 10/1) of the organic layer gave the sulfoxide. To a stirred xylene solution (40 mL) of the sulfoxide was added $^iPr_2NEt$ (1.37 mL, 7.66 mmol) at room temperature, and the mixture was stirred at reflux temperature under Ar atmosphere for 1.5 h. Additional $^iPr_2NEt$ (1.37 mL, 7.66 mmol) was added to the reaction mixture, and the reaction was continued for 2 h. The reaction mixture was evaporated to dryness, and the residue was purified by HPLC (hexane/ethyl acetate = 400/1) to afford **9** (763 mg, 59%) as a syrup. **1,4-Anhydro-2-deoxy-3,5-*O*-(di-*tert*-butylsilylene)-4-thio-D-*erythro*-pent-1-enitol (11).** The reaction was carried out according to the procedure described above starting from **10** (2.78 g, 7.0 mmol)/CH_2Cl_2 (25 mL) and m-CPBA (2.05 g, 11.9 mmol)/CH_2Cl_2 (10 mL). Xylene solution (25 mL) of the sulfoxide was heated at reflux temperature in the presence of $^iPr_2NEt$ (5.4 mL, 31.15 mmol) under Ar atmosphere overnight. The reaction mixture was purified by HPLC (hexane/ethyl acetate = 400/1) to afford **11** (1.09 g, 57% from **10**) as a solid.

1-[3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-2-phenylseleno-4-thio-b-D-ribofuranosyl]uracil (13*β*) and 1-[3,5-Bis-*O*-(*tert*-butyldimethylsilyl)-2-deoxy-2-phenylseleno-4-thio-α-D-ribofuranosyl]uracil (13α). To a stirred CH_3CN (2 mL) solution of **5** (59.9 mg, 0.17 mmol) and bis-*O*-trimethylsilyluracil (64 *μ*L, 0.25 mmol) was added an CH_3CN (1 mL) solution of PhSeCl (59,9 mg, 0.26 mmol) at 0 °C under Ar atmosphere. After 1 h, the reaction mixture was partitioned between $CHCl_3$/sat. $NaHCO_3$. Silica gel column chromatography (hexane/ethyl acetate = 6/1) of the organic layer gave a mixture of **13***β* and **13**α (91.2 mg, 88%, **13***β*/**13**α = 4/1) as a foam. Compound **13**α and **13***β* were separated by HPLC (hexane/ethyl acetate = 2/1).

13*β*: mp 186−187 °C; UV (MeOH) λ_{max} 267 nm (ϵ 9500), λ_{max} 241 nm (ϵ 5600); ^1H NMR ($CDCl_3$) δ 0.09, 0.10, 0.16 and 0.21 (12H, each as s), 0.93 and 0.97 (18H, each as s), 3.42 (1H, ddd, $J_{3',4'}$ = 0.9, $J_{4',5a'}$ = 6.7 and $J_{4',5b'}$ = 3.7 Hz), 3.63 (1H, dd, $J_{4',5a'}$ = 6.7 and $J_{5a',5b'}$ = 11.0 Hz), 3.75 (1H, dd, $J_{2',3'}$ = 3.4, $J_{1',2'}$ = 9.8 Hz), 3.86 (1H, dd, $J_{4',5'b}$ = 3.7 and $J_{5'a,5'b}$ = 11.0 Hz), 4.65 (1H, dd, $J_{3',4'}$ = 0.9 and $J_{2',3'}$ = 3.4 Hz), 5.37 (1H, dd, $J_{5,NH}$ = 2.5 and $J_{5,6}$ = 8.1 Hz), 6.58 (1H, d, $J_{1,2}$ = 9.8 Hz), 7.16−7.20, 7.23−7.26, 7.48−7.50 (5H, each as m), 7.38 (1H, d, $J_{5,6}$ = 8.1 Hz), 8.59 (1H, br-s); FAB-MS *m*/*z* 629 (M^+ + H), 571(M^+ − ^{t}Bu). Anal. Calcd for $C_{27}H_{44}N_2O_4SSeSi_2$: C, 51.65; H, 7.06; N, 4.46. Found: C, 51.74; H, 7.00; N, 4.44. **13**α: mp 172−173 °C; UV (MeOH) λ_{max} 266 nm (ϵ 11400), λ_{max} 235 nm (ϵ 6000); ^1H NMR ($CDCl_3$) δ -0.06, −0.02, 0.11 and 0.12 (12H, each as s), 0.81 and 0.93 (18H, each as s), 3.65−3.70 (2H, m), 3.81 (1H, dd, $J_{4',5a'}$ = 6.4 and $J_{5a',5b'}$ = 10.2 Hz), 4.05 (1H, dd, $J_{4',5'b}$ = 7.6 and $J_{5'a,5'b}$ = 10.2 Hz), 4.53 (1H, t, $J_{3',4'}$ = $J_{2',3'}$ = 3.1 Hz), 5.59 (1H, dd, $J_{5,NH}$ = 2.1 and $J_{5,6}$ = 8.2 Hz), 6.31 (1H, d, $J_{1,2}$ = 4.3 Hz), 7.28−7.35, 7.64−7.66 (5H, each as m), 7.85 (1H, d, $J_{5,6}$ = 8.2 Hz), 8.82 (1H, br-s, NH); FAB-MS *m*/*z* 629 (M^+ + H), 571 (M^+ − ^{t}Bu). Anal. Calcd for $C_{27}H_{44}N_2O_4SSeSi_2$: C, 51.65; H, 7.06; N, 4.46. Found: C, 51.75; H, 6.93; N, 4.42.

1-[2-Deoxy-2-phenylseleno-3,5-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-4-thio-*β*-D-ribofuranosyl]uracil (14*β*) and 1-[2-Deoxy-2-phenylseleno-3,5-*O*-(1,1,3,3-tetraisopropyldisiloxane-1,3-diyl)-4-thio-α-D-ribofuranosyl]-uracil (14α). The reaction mixture was carried out according to the procedure described for the preparation of **13** starting from **9** (49.5 mg, 0.13 mmol), bis-*O*-trimethylsilyluracil (51 *μ*L, 0.20 mmol), and PhSeCl (37.9 mg, 0.20 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 6/1) of the crude product gave a mixture of **14***β* and **14**α (71.2 mg, 87%, **14***β*/**14**α = 18/1) as a foam. The mixture of **14***β* and **14**α was separated by preparative TLC (hexane/ethyl acetate = 3/1). **14***β*: syrup, UV (MeOH) λ_{max} 266 nm (ϵ 11000), λ_{max} 239 nm (ϵ 5500); ^1H NMR ($CDCl_3$) δ 1.05−1.12 (28H, m), 3.78−3.81 (2H, m), 3.98 (1H, dd, $J_{4',5a'}$ = 3.7 and $J_{5a',5b'}$ = 12.7 Hz), 4.12 (1H, dd, $J_{4',5'b}$ = 3.4 and $J_{5'a,5'b}$ = 12.7 Hz), 4.56 (1H, dd, $J_{3',4'}$ = 7.0 and $J_{2',3'}$ = 5.2 Hz), 5.54 (1H, d, $J_{5,6}$ = 8.0 Hz), 6.02 (1H, d, $J_{1,2}$ = 3.4 Hz), 7.21−7.33, 7.71−7.73 (5H, each as m), 8.04 (1H, d, $J_{5,6}$ = 8.0 Hz), 9.00 (1H, br-s); FAB-MS *m*/*z* 599 (M^+ − ^{i}Pr). Anal. Calcd for $C_{27}H_{42}N_2O_5SSeSi_2$: C, 50.53; H, 6.60; N, 4.36. Found: C, 50.76; H, 6.61; N, 4.31.

14α: syrup, UV (MeOH) λ_{max} 267 nm (ϵ 10600), λ_{max} 234 nm (ϵ 6800); ^1H NMR ($CDCl_3$) δ 1.06−1.13 (28H, m), 3.59−3.62 (1H, m), 3.76 (1H, dd, $J_{2',3'}$ = 10.1 and $J_{1',2'}$ = 9.2 Hz), 3.90 (1H, dd, $J_{4',5'a}$ = 4.0 and $J_{5a',5b'}$ = 12.5 Hz), 4.13 (1H, dd, $J_{4',5'b}$ = 2.8, $J_{5'a,5'b}$ = 12.5 Hz), 4.28 (1H, dd, $J_{3',4'}$ = 8.2 and $J_{2',3'}$ = 10.1 Hz), 5.53 (1H, d, $J_{5,NH}$ = 2.2 and $J_{5,6}$ = 8.3 Hz), 6.22 (1H, d, $J_{1,2}$ = 9.2 Hz), 7.26−7.29, 7.53−7.55 (6H, each as m), 7.79 (1H, br); FAB-MS *m*/*z* 643 (M^+ + H), 599 (M^+ − ^{i}Pr). Anal. Calcd for $C_{27}H_{42}N_2O_5SSeSi_2$: C, 50.53; H, 6.60; N, 4.36. Found: C, 50.69; H, 6.61; N, 4.29.

1-[3,5-*O*-(Di-*tert*-butylsilylene)-2-deoxy-2-phenylseleno-4-thio-*β*-D-ribofuranosyl]uracil (15*β*). The reaction was carried out according to the procedure described for the preparation of **13** starting from **11** (32.7 mg, 0.17 mmol), bis-*O*-trimethylsilyluracil (44 *μ*L, 0.17 mmol), and PhSeCl (32.7 mg, 0.17 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 2/1) of the crude product gave **15***β* (54.4 mg, 88%) as a white solid; mp 143−144 °C; UV (MeOH) λ_{max} 266 nm (ϵ 12400), λ_{max} 239 nm (ϵ 6200); ^1H NMR ($CDCl_3$) δ 1.06 and 1.08 (18H, each as s), 3.88 (1H, ddd, $J_{3',4'}$ = 12.7 and $J_{4',5'a}$ = 8.1 and $J_{4',5'b}$ = 4.6 Hz), 4.15−4.19 (2H, m), 4.43 (1H, dd, $J_{4',5'b}$ = 4.6 and $J_{5'a,5'b}$ = 10.1 Hz), 4.47 (1H, dd, $J_{3',4'}$ = 12.7 and $J_{2',3'}$ = 5.8 Hz), 5.68 (1H, dd, $J_{5,NH}$ = 1.9 and $J_{5,6}$ = 8.1 Hz), 5.90 (1H, d, $J_{1,2}$ = 1.2 Hz), 7.28−7.35, 7.71−7.73 (5H, each as m), 7.55 (1H, d, $J_{5,6}$ = 8.1 Hz), 9.11 (1H, br-s); FAB-MS *m*/*z* 541 (M^+ + H), 483 (M^+ − ^{t}Bu). Anal. Calcd for $C_{23}H_{32}N_2O_4SSeSi$: C, 51.19; H, 5.98; N, 5.19. Found: C, 51.38; H, 5.85; N, 5.15.

1-[3,5-*O*-(Di-*tert*-butylsilylene)-2-deoxy-2-iodo-4-thio-*β*-D-ribofuranosyl]uracil (16*β*). The reaction mixture was carried out according to the procedure described for the preparation of **13** starting from **11** (43.1 mg, 0.16 mmol), bis-*O*-trimethylsilyluracil (61 *μ*L, 0.24 mmol), and NIS (53.3 mg, 0.24 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 3/1) of the crude product gave **16***β* (58.7 mg, 88%) as a foam; UV (MeOH) λ_{max} 263 nm (ϵ 14600), λ_{max} 238 nm (ϵ 10200); ^1H NMR ($CDCl_3$) δ 1.04 and1.08 (18H, each as s), 3.12 (1H, dd, $J_{2',3'}$ = 4.6 and $J_{3',4'}$ = 9.5 Hz), 3.69−3.76 (1H, m), 4.25 (1H, t, $J_{4',5'b}$ = $J_{5'a,5'b}$ = 10.4 Hz), 4.46 (1H, dd, $J_{4',5'b}$ = 4.9 and $J_{5'a,5b'}$ = 10.4 Hz), 4.64 (1H, d, $J_{2',3'}$ = 4.6 Hz), 5.81 (1H, d, $J_{5,6}$ = 8.3 Hz), 6.18 (1H, s), 7.96 (1H, d, $J_{5,6}$ = 8.3 Hz), 9.58 (1H, br); FAB-MS *m*/*z* 511 (M^+ + H), 453 (M^+ − ^{t}Bu). Anal. Calcd for $C_{17}H_{27}IN_2O_4SSi$: C, 40.00; H, 5.33; N, 5.49. Found: C, 40.30; H, 5.57; N, 5.32.

1-[3,5-*O*-(Di-*tert*-butylsilylene)-2-deoxy-2-phenylseleno-4-thio-*β*-D-ribofuranosyl]thymine (17*β*). The reaction was carried out according to the procedure described for the preparation of **13** starting from **11** (38.1 mg, 0.14 mmol), bis-*O*-trimethylsilylthymine prepared from thymine (26.5 mg, 0.2 mmol) and *N*,*O*-bis-trimethylsilylacetamide (BSA) (0.1 mL, 0.42 mmol), and PhSeCl (61.7 mg, 0.32 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 3/1) of the crude product gave **17***β* (48.1 mg, 62%) as a foam; UV (MeOH) λ_{max} 271 nm (ϵ 11700), λ_{max} 236 nm (ϵ 5500); ^1H NMR ($CDCl_3$) δ 1.07 and 1.08 (18H, each as s), 1.86 (3H, s), 3.84−3.89 (1H, m), 4.18 (1H, dd, $J_{4',5'a}$ = 10.4 and $J_{5'a,5'b}$ = 11.1 Hz), 4.23 (1H, dd, $J_{1',2'}$ = 1.9 and $J_{2',3'}$ = 6.1 Hz), 4.42 (1H, dd, $J_{4',5'b}$ = 4.6, $J_{5'a,5'b}$ = 11.1 Hz), 4.60 (1H, dd, $J_{3',4'}$ = 9.6 and $J_{2',3'}$ = 6.1 Hz), 5.88 (1H, d, $J_{1,2}$ = 1.9 Hz), 7.11 (1H, d, $J_{6,Me}$ = 1.2 Hz), 7.28−7.35, 7.69−7.71 (5H, each as m), 8.61 (1H, br); FAB-MS *m*/*z* 555 (M^+ + H), 497 (M^+ − ^{t}Bu). Anal. Calcd for

$C_{23}H_{32}N_2O_4SSeSi$: C, 52.07; H, 6.19; N, 5.06. Found: C, 51.91; H, 6.10; N, 5.12.

N*⁴-Acetyl-[3,5-*O*-(Di-*tert*-butylsilylene)-2-deoxy-2-phenylseleno-4-thio-*β*-D-ribofuranosyl]cytosine (18*β*).** The reaction was carried out according to the procedure described for the preparation of **13** starting from **11** (81.7 mg, 0.30 mmol), 1-*O*-trimethylsilyl-*N*⁴-acetylcytosine prepared from *N*⁴-acetylcytosine (68.9 mg, 0.45 mmol) and BSA (0.1 mL, 0.45 mmol), and PhSeCl (86.2 mg, 0.45 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 1/1) of crude product gave **18β* (148.9 mg, 85%) as a solid; mp 243−244 °C; UV (MeOH) λ_{max} 281 nm (ϵ 9870) and 244 nm, (15100) λ_{max} 232 nm (ϵ 13200); ^{1}H NMR ($CDCl_3$) δ 1.04 and1.07 (18H, each as s), 3.85−3.91 (1H, m), 4.11−4.19 (2H, m), 4.35 (1H, dd, $J_{3',4'}$ = 4.8 and $J_{2',3'}$ = 9.4 Hz), 4.43 (1H, dd, $J_{4',5'b}$ = 4.4 and $J_{5'a,5'b}$ = 10.2 Hz), 5.97 (1H, s), 7.24−7.30, 7.73−7.75 (5H, each as m), 7.37 (1H, d, $J_{5,6}$ = 7.2 Hz), 8.07 (1H, d, $J_{5,6}$ = 7.2 Hz), 9.45 (1H, br); FAB-MS *m*/*z* 582 ($M^+ + H$). Anal. Calcd for $C_{25}H_{35}N_3O_4SSeSi$: C, 51.71; H, 6.08; N, 7.24. Found: C, 51.63; H, 6.07; N, 7.10.

1-[3,5-Di-*O*-acetyl-2-deoxy-2-phenylseleno-4-thio-*β*-D-ribofuranosyl]uracil(19) (from 15*β*). To a stirred THF (3 mL) solution of **15***β* (50.4 mg, 0.09 mmol) and acetic anhydride (44 μL, 0.47 mmol) was added Bu_4NF (1 M THF solution) (0.28 mL, 0.28 mmol) at 0 °C under Ar atmosphere. The reaction mixture was stirred at room temperature overnight and partitioned between $CHCl_3$/sat. $NaHCO_3$. The organic layer was chromatographed by preparative TLC (hexane/ethyl acetate = 2/1) to afford **19** (25.7 mg, 57%) as a white solid, which was crystallized from ether-acetone; mp 168−169 °C; UV (MeOH) λ_{max} 265 nm (ϵ 9700), λ_{max} 240 nm (ϵ 5400); ^{1}H NMR ($CDCl_3$) δ 2.11 and 2.16 (6H, each as s), 3.70 (1H, ddd, $J_{3',4'}$ = 1.2, $J_{4',5a'}$ = 7.6 and $J_{4',5b'}$ = 5.5 Hz), 3.79 (1H, dd, $J_{1',2'}$ = 10.4 and $J_{2',3'}$ = 4.0 Hz), 4.22 (1H, dd, $J_{4',5'a}$ = 7.6 and $J_{5'a,5'b}$ = 11.6 Hz), 4.33 (1H, dd, $J_{4',5'b}$ = 5.5, $J_{5'a,5b'}$ = 11.6 Hz), 5.50 (1H, d, $J_{5,6}$ = 8.3 Hz), 5.53 (1H, dd, $J_{2',3'}$ = 4.0 and $J_{3',4'}$ = 1.2 Hz), 6.59 (1H, d, $J_{1',2'}$ = 10.4 Hz), 7.24−7.27, 7.30−7.34, 7.52−7.54 (6H, each as m), 8.17 (1H, br); FAB-MS *m*/*z* 485 ($M^+ + H$). Anal. Calcd for $C_{19}H_{20}N_2O_6SSe$: C, 47.21; H, 4.17; N, 5.80. Found: C, 47.11; H, 4.04; N, 5.71.

Preparation of 19 (from 14*β*). To a stirred THF (2 mL) solution of **14***β* (50.4 mg, 0.09 mmol) was added Bu_4NF (1 M THF solution) (0.14 mL, 0.14 mmol) at 0 °C under Ar atmosphere. After 3 h, the reaction mixture was evaporated to dryness, and the residue was dried in vacuo. To a stirred CH_2Cl_2 (2 mL) solution of the diol was added (dimethylamino)-pyridine (28.5 mg, 0.23 mmol) and acetic anhydride (18 μL, 0.19 mmol) at room temperature under Ar atmosphere. After 3 h, the reaction mixture was partitioned between chloroform/sat. $NaHCO_3$, and the organic layer was chromatographed by preparative TLC (hexane/ethyl acetate = 2/1) to afford **19** (15.4 mg, 68%) as a white solid.

Preparation of 1-[3,5-Di-*O*-acetyl-2-deoxy-2-phenylseleno-4-thio-α-D-ribofuranosyl]uracil (20) (from 14α). The reaction was carried out according to the procedure described for the preparation of **19** from **15b**, starting from **14**α (5.4 mg, 0.01 mmol), acetic anhydride (4.2 μL, 0.04 mmol), and Bu_4NF (1 M THF solution) (27 μL, 0.03 mmol). Usual workup and preparative TLC (hexane/ethyl acetate = 1/1) afforded **20** (3 mg, 70%) as a syrup; UV (MeOH) λ_{max} 264 nm (ϵ 10800), λ_{max} 236 nm (ϵ 5500); ^{1}H NMR ($CDCl_3$) δ 2.06 and 2.09 (6H, each as s), 3.75 (1H, dd, $J_{1',2'}$ = 8.0 and $J_{2',3'}$ = 8.9 Hz), 3.87−3.91 (1H, m), 4.16 (1H, dd, $J_{4',5'a}$ = 7.0 and $J_{5'a,5'b}$ = 11.6 Hz), 4.37 (1H, dd, $J_{4',5'b}$ = 5.5 and $J_{5'a,5b'}$ = 11.6 Hz), 5.25 (1H, dd, $J_{2',3'}$ = 8.9 and $J_{3',4'}$ = 7.0 Hz), 5.71 (1H, d, $J_{1',2'}$ = 8.0 Hz), 6.19 (1H, d, $J_{5,6}$ = 8.3 Hz), 7.31−7.34, 7.36−7.39, 7.62−7.65 (5H, each as m), 7.45 (1H, d, $J_{5,6}$ = 8.3 Hz), 7.99 (1H, br); FAB-MS *m*/*z* 485 ($M^+ + H$). Anal. Calcd for $C_{19}H_{20}N_2O_6SSe$: C, 47.21; H, 4.17; N, 5.80. Found: C, 47.44; H, 3.91; N, 5.65.

Preparation of 19 and 20 (from 13*β* and 13α). The reaction was carried out according to the procedure for the preparation of **19** from **14b**, starting from a mixture of **13***β* and **13***β* (90.2 mg, 0.14 mmol), Bu_4NF (1 M THF solution) (0.43 mL, 0.43 mmol), (dimethylamino)pyridine (88 mg, 0.72 mmol), and acetic anhydride (54 μL, 0.58 mmol). Usual workup and preparative TLC (hexane/ethyl acetate = 1/1) afforded **19** (38.9 mg, 56%, as a solid) and **20** (10 mg, 4%, as a syrup).

***N*⁶-Benzoyl-9-[3,5-*O*-(di-*tert*-butylsilylene)-2-deoxy-2-phenylseleno- 4-thio-*β*-D-ribofuranosyl]adenine (21), *N*⁶-Benzoyl-7-[3,5-*O*-(di-*tert*-butylsilylene)-2-deoxy-2-phenylseleno-4-thio-*β*-D-ribofuranosyl]adenine (22), and *N*⁶-Benzoyl-1-[3,5-*O*-(di-*tert*-butylsilylene)-2-deoxy-2-phenylseleno-4-thio-*β*-D-ribofuranosyl]adenine (23). Method A.** The reaction mixture was carried out according to the procedure described for the preparation of **13** starting from **11** (81.7 mg, 0.3 mmol), *N*⁶-benzoyladenine (107.6 mg, 0.45 mmol), BSA (0.22 mL, 0.9 mmol), and phenylselenenyl chloride (86.2 mg, 0.45 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 1/1) of the crude product and subsequent preparative TLC gave **21** (12.6 mg, 6%, foam), **22** (25.3 mg, 13%, foam), and **23** (59.1 mg, 30%, foam);

Method B. The reaction was carried out according to the procedure described for the preparation of **13** starting from **11** (81.7 mg, 0.3 mmol), *N*⁶-benzoyladenine (107.6 mg, 0.45 mmol), BSA (0.11 mL, 0.45 mmol), and phenylselenenyl chloride (86.2 mg, 0.45 mmol). Usual workup, silica gel column chromatography (hexane/ethyl acetate = 1/1) and subsequent preparative TLC of the crude product gave **21** (102.4 mg, 51%, solid), **22** (3.4 mg, 2%, syrup), and **23** (4.5 mg, 2%, syrup).

21: mp 119−120 °C; UV (MeOH) λ_{max} 280 nm (ϵ 23300), λ_{max} 253 nm (ϵ 12300); ^{1}H NMR ($CDCl_3$) δ 1.08 (18H, s), 3.90−4.04 (1H, m), 4.23 (1H, t, $J_{4',5'a}$ = $J_{5'a,5'b}$ = 10.5 Hz), 4.30−4.36 (2H, m), 4.47 (1H, dd, $J_{4',5'b}$ = 4.6 and $J_{5'a,5'b}$ = 10.5 Hz), 4.67−4.76 (1H, m), 6.91−6.94, 7.05−7.07, 7.35−7.36, 7.51−7.54, 7.57−7.60, and 8.40−8.41 (10H, each as m), 7.40 (1H, s), 8.24 and 8.50 (2H, each as s); NOE-experiment, H-1′/H-4′(1.8%), H-8/H-5′(1.9%), H-8/H-3′(5.5%); FAB-MS *m*/*z* 668 ($M^+ + H$). Anal. Calcd for $C_{31}H_{37}N_5O_3SSeSi$: C, 55.84; H, 5.59; N, 10.50. Found: C, 55.95; H, 5.44; N, 10.50.

22: UV (MeOH) λ_{max} 333 nm (ϵ 15500), λ_{min} 299 nm (ϵ 6300); ^{1}H NMR ($CDCl_3$) δ 1.09 and1.10 (18H, each as s), 3.95−4.00 (1H, m), 4.31 (1H, t, $J_{4',5'a}$ = $J_{5'a,5'b}$ = 11.0 Hz), 4.43−4.47 (2H, m), 5.20 (1H, dd, J = 5.5 and J = 9.5 Hz), 6.02 (1H, s), 7.30−7.38, 7.50−7.53, 7.59−7.62, 7.71−7.73, and 8.00−8.01 (10H, each as m), 7.89 and 8.63 (2H, each as s), 9.00 (1H, br-s); NOE-experiment, H-1′/H-4′ (1.2%), H-8/H-5′ (0.7%), H-8/H-3′ (5.7%), H-2′/H-3′ (6.6%); FAB-MS *m*/*z* 668 ($M^+ + H$). Anal. Calcd for $C_{31}H_{37}N_5O_3SSeSi$: C, 55.84; H, 5.59; N, 10.50. Found: C, 55.84; H, 5.54; N, 10.10.

23: UV (MeOH) λ_{max} 333 nm (ϵ 15100), λ_{max} 297 nm (ϵ 6600); ^{1}H NMR ($CDCl_3$) δ 1.05 and1.07 (18H, each as s), 4.01−4.06 (1H, m), 4.27 (1H, t, $J_{4',5'a}$ = $J_{5'a,5'b}$ = 10.5 Hz), 4.38 (1H, d, $J_{2',3'}$ = 9.5 Hz), 4.49 (1H, dd, $J_{4',5'b}$ = 4.6 and $J_{5'a,5'b}$ = 10.5 Hz), 4.63 (1H, dd, $J_{2',3'}$ = 5.2 and $J_{3',4'}$ = 9.5 Hz), 7.12 (1H, s), 6.96−6.99, 7.05−7.09, 7.40−7.43, 7.47−7.54, and 8.29−8.30 (10H, each as m), 8.10 and 8.91 (2H, each as s); NOE-experiment, H-1′/H-4′ (1.1%), H-8/H-5′ (1.2%), H-8/H-3′ (10.4%), H-2′/H-3′ (7.9%); FAB-MS *m*/*z* 668 ($M^+ + H$). Anal. Calcd for $C_{31}H_{37}N_5O_3SSeSi$: C, 55.84; H, 5.59; N, 10.50. Found: C, 55.99; H, 5.63; N, 10.16.

***N*⁶-Benzoyl-9-[3,5-*O*-(di-*tert*-butylsilylene)-2-deoxy-4-thio-*β*-D-ribofuranosyl]adenine (24).** To a stirred benzene (2 mL) solution of **21** (13 mg, 0.019 mmol) were added Bu_3SnH (15 μL, 0.057 mmol) and Et_3B (1 M THF solution) (19 μL, 0.019 mmol), and the reaction mixture was stirred at room temperature under O_2 atmosphere. After 1 h, the reaction mixture was purified by preparative TLC (hexane/ethyl acetate = 1/1) to give **24** (6.3 mg, 65%) as a solid, which was cryatallized from MeOH; mp 246−247 °C; UV (MeOH) λ_{max} 277 nm (ϵ 14900), λ_{max} 247 nm (ϵ 9900); ^{1}H NMR ($CDCl_3$) δ 1.03 and 1.07 (18H, each as s), 2.45 (1H, ddd, $J_{1',2'a}$ = 6.0, $J_{2'a,3'}$ = 9.6, and $J_{2'a,2'b}$ = 10.7 Hz), 2.72 (1H, dd, $J_{2'b,3'}$ = 4.2, and $J_{2'a,2'b}$ = 10.7 Hz), 3.50 (1H, ddd, $J_{3',4'}$ = 7.6, $J_{4',5'a}$ = 8.8, and

$J_{4',5'b}$ = 3.7 Hz), 4.17 (1H, dd, $J_{4',5'a}$ = 8.8 and $J_{5'a,5'b}$ = 8.2 Hz), 4.41 (1H, dd, $J_{4',5'b}$ = 3.7 and $J_{5'a,5'b}$ = 8.2 Hz), 4.64 (1H, ddd, $J_{2'a,3'}$ = 9.6, $J_{2'b,3'}$ = 4.2, and $J_{3',4'}$ = 7.6 Hz), 6.21 (1H, d, $J_{1',2'a}$ = 6.0 Hz), 7.51−7.55, 7.60−7.63, and 8.02−8.04 (5H, each as m), 8.39 and 8.79 (2H, each as s), 9.00 (1H, br); FAB-MS *m*/*z* 512 ($M^+ + H$). Anal. Calcd for $C_{25}H_{33}N_5O_3SSi$: C, 58.68; H, 6.50; N, 13.69. Found: C, 58.66; H, 6.42; N, 13.71.

***N*⁶-Benzoyl-7-[3,5-*O*-(di-*tert*-butylsilylene)-2-deoxy-4-thio-*β*-D-ribofuranosyl]adenine (25).** The reaction was carried out according to the procedure for the preparation of **24** starting from **22** (25 mg, 0.037 mmol), Bu_3SnH (30 μL, 0.11 mmol), and Et_3B (1 M THF solution) (37 μL, 0.037 mmol). Usual workup and preparative TLC (hexane/ethyl acetate = 1/1) gave **25** (13.9 mg, 74%) as a solid, which was cryatallized from MeOH; mp 257−259 °C; UV (MeOH) λ_{max} 397 nm (ε 1200), λ_{max} 329 nm (ε 18600), λ_{min} 378 nm (ε 800), λ_{min} 296 nm (ε 7700); ^{1}H NMR ($CDCl_3$) δ 1.03 and 1.04 (18H, each as s), 2.53−2.60 (1H, m), 2.84 (1H, dd, $J_{2'b,3'}$ = 4.1, and $J_{2'a,2'b}$ = 11.0 Hz), 3.55−3.60 (1H, m), 4.16 (1H, t, $J_{4',5'a}$ = $J_{5'a,5'b}$ = 8.5 Hz), 4.39−4.45 (2H, m), 6.98 (1H, d, $J_{1',2'a}$ = 5.3 Hz), 7.48−7.51, 7.54−7.57, and 8.26−8.30 (5H, each as m), 8.30 and 8.67 (2H, each as s), 15.59 (1H, br); FAB-MS *m*/*z* 512 ($M^+ + H$). Anal. Calcd for $C_{25}H_{33}N_5O_3SSi$: C, 58.68; H, 6.50; N, 13.69. Found: C, 58.58; H, 6.56; N, 13.55.

***N*⁶-Benzoyl-1-[3,5-*O*-(di-*tert*-butylsilylene)-2-deoxy-4-thio-*β*-D-ribofuranosyl]adenine (26).** The reaction was carried out according to the procedure for the preparation of **24** starting from **23** (57.6 mg, 0.086 mmol), Bu_3SnH (70 μL, 0.26 mmol), and Et_3B (1 M THF solution) (86 μL, 0.086 mmol). Usual workup and preparative TLC (hexane/ethyl acetate = 1/1) gave **26** (35.3 mg, 80%) as a solid, which was cryatallized from MeOH; mp 229−231 °C; UV (MeOH) λ_{max} 396 nm (ε 1200), λ_{max} 332 nm (ε 46100), λ_{min} 379 nm (ε 800), λ_{min} 293 nm (ε 6900); ^{1}H NMR ($CDCl_3$) δ 1.04 and1.06 (18H, each as s), 2.60 (1H, ddd, $J_{1',2'a}$ = 6.3, $J_{2'a,3'}$ = 9.9, and $J_{2'a,2'b}$ = 11.4 Hz), 2.81 (1H, dd, $J_{2'b,3'}$ = 4.4, and $J_{2'a,2'b}$ = 11.4 Hz), 3.56 and 3.50 (1H, ddd, $J_{3',4'}$ = 7.6, $J_{4',5'a}$ = 8.7, and $J_{4',5'b}$ = 3.7 Hz), 4.14 (1H, t, $J_{4',5'a}$ = $J_{5'a,5'b}$ = 8.7 Hz), 4.40 (1H, dd, $J_{4',5'b}$ = 3.7 and $J_{5'a,5'b}$ = 8.7 Hz), 4.51 (1H, ddd, $J_{2'a,3'}$ = 9.9, $J_{2'b,3'}$ = 4.4 and $J_{3',4'}$ = 7.6 Hz), 6.90 (1H, d, $J_{1',2'a}$ = 6.3 Hz), 7.46−7.49, 7.53−7.57, and 8.31−8.32 (5H, each as m), 8.16 and 8.98 (2H, each as s), 12.66 (1H, br); FAB-MS *m*/*z* 512 ($M^+ + H$). Anal. Calcd for $C_{25}H_{33}N_5O_3SSi$: C, 58.68; H, 6.50; N, 13.69. Found: C, 58.55; H, 6.50; N, 13.66.

9-[3,5-*O*-(Di-*tert*-butylsilylene)-2-deoxy-4-thio-*β*-D-ribofuranosyl]adenine (27). Methanolic ammonia (3 mL) was added to **24** (19 mg, 0.037 mmol), and the mixture was kept at room temperature for 5 h. The reaction mixture was chromatographed by preparative TLC (hexane/ethyl acetate = 1/1) to give **27** (4 mg, 26%) as a foam; UV (MeOH) λ_{max} 261 nm (ε 13900), λ_{min} 230 nm (ε 1700); ^{1}H NMR ($CDCl_3$) δ 1.02 and 1.06 (18H, each as s), 2.41 (1H, ddd, $J_{1',2'a}$ = 7.4, $J_{2'a,3'}$ = 12.0, and $J_{2'a,2'b}$ = 13.5 Hz), 2.68 (1H, dd, $J_{2'b,3'}$ = 5.2 and $J_{2'a,2'b}$ = 13.5 Hz), 3.48 (1H, ddd, $J_{3',4'}$ = 9.6, $J_{4',5'a}$ = 11.2 and $J_{4',5'b}$ = 4.6 Hz), 4.16 (1H, t, $J_{4',5'a}$ = $J_{5'a,5'b}$ = 11.2 Hz), 4.39 (1H, dd, $J_{4',5'b}$ = 4.6 and $J_{5'a,5'b}$ = 11.2 Hz), 4.62 (1H, ddd, $J_{2'a,3'}$ = 12.0, $J_{2'b,3'}$ = 5.2 and $J_{3',4'}$ = 9.6 Hz), 5.63 (2H, br), 6.13 (1H, d, $J_{1',2'a}$ = 7.4 Hz), 8.16 and 8.36 (2H, each as s); FAB-MS *m*/*z* 408 ($M^+ + H$). Anal. Calcd for $C_{25}H_{33}N_5O_3SSi$: C, 53.04; H, 7.17; N, 17.18. Found: C, 53.29; H, 7.37; N, 16.84.

1-[3,5-*O*-(Di-*tert*-butylsilylene)-2-deoxy-4-thio-*β*-D-ribofuranosyl]uracil(28) (prepared from 15*β*). The reaction was carried out according to the procedure for the preparation of **24** starting from **15***β* (159 mg, 0.29 mmol), Bu_3SnH (0.23 mL, 0.87 mmol), and Et_3B (1 M THF solution) (0.29 mL, 0.29 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 3/1) afforded **28** (76.5 mg, 69%) as a white solid; mp 226−228 °C; UV (MeOH) λ_{max} 265 nm (ε 10500), λ_{max} 213 nm (ε 9300) and λ_{max} 233 nm (ε 2800); ^{1}H NMR ($CDCl_3$) δ 1.00 and 1.06 (18H, each as s), 2.32 (1H, ddd, $J_{1',2'a}$ = 8.2, $J_{2'a,3'}$ = 11.9 and $J_{2'b,2'b}$ = 13.7 Hz), 2.41 (1H, ddd, $J_{1',2'b}$ = 1.2, $J_{2'b,3'}$ = 6.0 and $J_{2'b,2'b}$ = 13.7 Hz), 3.38 (1H, ddd, $J_{3',4'}$ = 9.6, $J_{4',5'a}$ = 11.0 and $J_{4',5'b}$ = 4.6 Hz), 4.08 (1H, dd, $J_{4',5'a}$ = 11.0 and $J_{5'a,5'b}$ = 10.1 Hz), 4.29 (1H, ddd, $J_{2'a,3'}$ = 11.9, $J_{2'b,3'}$ = 6.0 and $J_{3',4'}$ = 9.6 Hz), 4.36 (1H, dd, $J_{4',5'b}$ = 4.6 and $J_{5'a,5'b}$ = 7.0 Hz), 5.83 (1H, dd, $J_{5,NH}$ = 2.4 and $J_{5,6}$ = 8.2 Hz), 6.18 (1H, dd, $J_{1',2'a}$ = 8.2 and $J_{1',2'b}$ = 1.2 Hz), 7.77 (1H, d, $J_{5,6}$ = 8.2 Hz), 9.13 (1H, br-s); FAB-MS *m*/*z* 385 ($M^+ + H$), 327 ($M^+ - {}^tBu$). Anal. Calcd for $C_{17}H_{28}N_2O_4SSi \cdot 1/3H_2O$: C, 52.28; H, 7.40; N, 7.17. Found: C, 52.49; H, 7.73; N, 7.08.

1-[3,5-*O*-(Di-*tert*-butylsilylene)-2-deoxy-4-thio-*β*-D-ribofuranosyl]thymine(29). The reaction was carried out according to the procedure for the preparation of **24** starting from **17***β* (42.4 mg, 0.08 mmol), Bu_3SnH (62 μL, 0.23 mmol), and Et_3B (1 M THF solution) (77 mL, 0.77 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 1/1) afforded **29** (18.9 mg, 62%) as a white solid; mp 239−241 °C; UV (MeOH) λ_{max} 271 nm (ε 10000) and λ_{min} 237 nm (ε 2100); ^{1}H NMR ($CDCl_3$) δ 1.01 and 1.08 (18H, each as s), 1.97 (3H, d, $J_{Me,6}$ = 1.3 Hz), 2.32 (1H, ddd, $J_{1',2'a}$ = 8.27, $J_{2'a,3'}$ = 11.9 and $J_{2'b,2'b}$ = 12.8 Hz), 2.40 (1H, ddd, $J_{1',2'b}$ = 1.0, $J_{2'b,3'}$ = 6.1 and $J_{2'b,2'b}$ = 12.8 Hz), 3.38 (1H, ddd, $J_{3',4'}$ = 9.8, $J_{4',5'a}$ = 11.0 and $J_{4',5'b}$ = 4.6 Hz), 4.10 (1H, dd, $J_{4',5'a}$ = 11.0 and $J_{5'a,5'b}$ = 10.4 Hz), 4.36 (1H, dd, $J_{4',5'b}$ = 4.6 and $J_{5'a,5'b}$ = 10.4 Hz), 4.32−4.38 (1H, m), 6.20 (1H, dd, $J_{1',2'a}$ = 8.7 and $J_{1',2'b}$ = 1.0 Hz), 7.49 (1H, q, $J_{Me,6}$ = 1.3 Hz), 8.57 (1H, br); FAB-MS *m*/*z* 399 ($M^+ + H$), 341 ($M^+ - {}^tBu$). Anal. Calcd for $C_{18}H_{30}N_2O_4SSi \cdot 1/4H_2O$: C, 53.63; H, 7.63; N, 6.95. Found: C, 54.24; H, 7.59; N, 7.03.

1-[3,5-*O*-(Di-*tert*-butylsilylene)-2-deoxy-4-thio-*β*-D-ribofuranosyl]uracil (28) (prepared from 16*β*). The reaction was carried out according to the procedure for the preparation of **24** starting from **16***β* (58.2 mg, 0.11 mmol), Bu_3SnH (92 μL, 0.34 mmol), and Et_3B (1 M THF solution) (0.11 mL, 0.11 mmol). Usual workup and silica gel column chromatography (hexane/ethyl acetate = 3/1) afforded **28** (26.6 mg, 61%) as a white solid.

2,2′-Anhydro-[1-{3,5-*O*-(di-*tert*-butylsilylene)-2-deoxy-4-thio-*β*-D-ribofuranosyl}uracil] (30). To a stirred CH_3CN (5 mL) solution of **16***β* (81.9 mg, 0.16 mmol) was added DBN (59 μL, 0.48 mmol) at 0 °C under Ar atmosphere. After 3 h, the reaction mixture was neutralized with AcOH and partitioned between $CHCl_3$/sat. $NaHCO_3$. Silica gel column chromatography (2% MeOH in $CHCl_3$) of the organic layer gave **30** (58.5 mg, 95%) as a solid; mp 260−261 °C; UV (MeOH) λ_{max} 255 nm (ε 8500), λ_{max} 242 nm (ε 7200); ^{1}H NMR ($CDCl_3$) δ 1.02 and1.06 (18H, each as s), 3.55 (1H, dt, $J_{4',5'b}$ = 4.6 and $J_{3',4'}$ = $J_{4',5'a}$ = 10.4 Hz), 4.02 (1H, t, $J_{4',5'a}$ = $J_{5'a,5'b}$ = 10.4 Hz), 4.32 (1H, dd, $J_{4',5'b}$ = 4.6 and $J_{5'a,5b'}$ = 10.4 Hz), 4.42 (1H, dd, $J_{2',3'}$ = 7.4 and $J_{3',4'}$ = 10.4 Hz), 5.19 (1H, dd, $J_{1',2'}$ = 8.2 and $J_{2',3'}$ = 7.4 Hz), 5.81 (1H, d, $J_{1',2'}$ = 8.2 Hz), 6.10 (1H, d, $J_{5,6}$ = 7.3 Hz), 7.14 (1H, d, $J_{5,6}$ = 7.3 Hz); FAB-MS *m*/*z* 383 ($M^+ + H$). Anal. Calcd for $C_{17}H_{26}N_2O_4SSi$: C, 53.37; H, 6.85; N, 7.32. Found: C, 53.39; H, 6.95; N, 7.20.

2,2′-Anhydro-[1-(4-thio-*β*-D-ribofuranosyl)uracil] (31). To a stirred THF (3 mL) solution of **30** (53.2 mg, 0.14 mmol) was added tetrabutylammonium fluoride (1 M THF solution) (0.31 mL, 0.31 mmol) under Ar atmosphere at 0 °C. After 2 h, the reaction mixture was chromatographed on a silica gel (7% MeOH in $CHCl_3$) to afford **31** (32.7 mg, 97%) as a white solid; mp 233−235 °C; UV (MeOH) λ_{max} 257 nm (ε 8200), λ_{max} 228 nm (ε 9700), and λ_{min} 242 nm (ε 6800); ^{1}H NMR (CD_3OD) δ 3.41−3.45 (1H, m), 3.51−3.57 (2H, m), 4.79 (1H, d, $J_{2',3'}$ = 0.8 Hz), 5.47 (1H, dd, $J_{2',3'}$ = 0.8 and $J_{1',2'}$ = 6.0 Hz), 6.08 (1H, d, $J_{5,6}$ = 6.0 Hz), 6.26 (1H, dd, $J_{1',2'}$ = 6.0 Hz), 7.79 (1H, d, $J_{5,6}$ = 6.0 Hz); FAB-MS *m*/*z* 281 ($M^+ + K$). Anal. Calcd for $C_9H_{10}N_2O_4S$: C, 44.62; H, 4.16; N, 11.56. Found: C, 44.33; H, 4.33; N, 11.33.

1-[2,3,5-Tris-*O*-(triethylsilyl)-4-thio-*β*-D-ribofuranosyl]-uracil] (33). To a stirred DMF (4 mL) solution of **31** (32.9 mg, 0.14 mmol) were added benzoic acid (24.9 mg, 0.2 mmol) and lithium benzoate (174 mg, 1.36 mmol) at room temperature, and the mixture was stirred at 140 °C under Ar atmosphere overnight. The reaction mixture was evaporated

to dryness, and the residue was chromatographed on a silica gel (3% MeOH in $CHCl_3$) to afford a mixture of regioisomers of the monobenzoate. To a stirred MeOH (3 mL) solution of the mixture was added 1.1 M NaOMe (0.86 mL, 0.95 mmol) at 0 °C under Ar atmosphere, and the mixture was stirred for 5 h at room temperature. The reaction mixture was neutralized with acetic acid and evaporated to dryness. The residue was chromtographed on a silica gel (6% MeOH in $CHCl_3$) to give the triol. To a stirred DMF (2 mL) solution of the triol were added imidazole (55.5 mg, 0.82 mmol) and triethylsilyl chloride (0.11 mL, 0.68 mmol) at 0 °C under Ar atmosphere. After 2 h, the reaction mixture was partitioned between ethyl acetate/H_2O and silica gel column chromatography (hexane/ethyl acetate = 15/1) of the organic layer gave **33** (42.7 mg, 52%) as a white solid; mp 75−77 °C; UV (MeOH) λ_{max} 267 nm (ϵ 10000), λ_{max} 214 nm (ϵ 7700), λ_{min} 230 nm (ϵ 4200); ^{1}H NMR ($CDCl_3$) δ 0.54−0.70 (18H, m), 0.92−1.03 (27H, m), 3.41−3.44 (1H, m), 3.76 (1H, dd, $J_{4',5'a}$ = 3.6 and $J_{5'a,5'b}$ = 11.2 Hz), 3.90 (1H, dd, $J_{4',5'b}$ = 3.6 and $J_{5'a,5'b}$ = 11.6 Hz), 4.37 (1H, dd, $J_{4',5'b}$ = 2.6 and $J_{5'a,5b'}$ = 11.2 Hz), 4.11 (1H, dd, $J_{2',3'}$ = 3.2 and $J_{3',4'}$ = 6.0 Hz), 4.14−4.16 (1H, m), 5.75 (1H, d, $J_{5,6}$ = 8.0 Hz), 5.82 (1H, d, $J_{1',2'}$ = 4.0 Hz), 8.34 (1H, d, $J_{5,6}$ = 8.0 Hz), 9.34 (1H, br); FAB-MS *m*/*z* 603 (M^+ + H), 573 (M^+ − Et). Anal. Calcd for $C_{27}H_{54}N_2O_5SSi_3$: C, 53.78; H, 9.03; N, 4.65. Found: C, 54.01; H, 9.23; N, 4.63.

1-(4-Thio-β-D-arabinofuranosyl)uracil (34). 1 M NaOH (3 mL) was added to **31** (69 mg, 0.29 mmol), and the mixture was stirred at room temperature for 1 h. The reaction mixture was neutralized with acetic acid and evaporated to dryness. The residue was chromatographed on a silica gel column (6% MeOH in $CHCl_3$) to give **34** (65 mg, 88%) as a white solid; mp 222−224 °C; UV (MeOH) λ_{max} 264 nm (ϵ 12400), λ_{mix} 238 nm (ϵ 9200); ^{1}H NMR (CD_3OD) δ 3.28−3.30 (1H, m), 3.86 (1H, dd, $J_{4',5'a}$ = 5.5 and $J_{5'a,5'b}$ = 11.3 Hz), 3.90 (1H, dd, $J_{4',5'b}$ = 4.6 and $J_{5'a,5'b}$ = 11.3 Hz), 4.08 (1H, t, $J_{2',3'} = J_{3',4'}$ = 6.1 Hz), 4.17 (1H, t, $J_{1',2'} = J_{2',3'}$ = 6.1 Hz), 5.68 (1H, d, $J_{5,6}$ = 7.9 Hz), 6.27 (1H, d, $J_{1',2'}$ = 6.1 Hz), 8.31 (1H, d, $J_{5,6}$ = 7.9 Hz); FAB-MS *m*/*z* 261 (M^+ + H). Anal. Calcd for $C_9H_{12}N_2O_5S$: C, 41.53; H, 4.65; N, 10.76. Found: C, 41.46; H, 4.54; N, 10.60.

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Supporting Information Available: Crystallographic data for **25**. This material is available free of charge via the Internet at http://pubs.acs.org.

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