1,1-Diphenyl-1-hydroxy[2,2,2-$^2H_3$]ethane (d-1-OH) was prepared from benzophenone and CD_3MgI (Aldrich, 1 M, 99+% ^2H) under dry nitrogen. Recrystallization from pentane gave pure product. The deuterium content in the methyl group was 99.6 ± 0.4 atom % (^1H NMR).

1,1-Diphenyl-1-phenoxyethane (1-OPh) was synthesized from **1-OH** by a modification of a previously published method.[17] Phenol (1.5 g, 16 mmol) and methylene chloride (0.5 mL) were added to 100 mg (0.5 mmol) of **1-OH**. After addition of zinc iodide (100 mg, 0.5 mmol), the mixture was stirred for 15 min under dry nitrogen. The reaction was stopped by adding pentane to the reaction flask. The filtered pentane solution was washed several times with water to remove the phenol and once with brine. Analysis by HPLC showed 52% conversion of the alcohol to give 78% of the ether and 22% of olefin **3**. A longer reaction time reduces the ratio of ether to olefin quite quickly. The required ether was purified by semipreparative HPLC.

1,1-Diphenyl-1-chloroethane (1-Cl). Method 1. A total of 15 mg of **1-OH** partially dissolved in 0.6 mL of hexane was shaken with 0.6 mL of concentrated hydrochloric acid. After 2 min, the organic phase was separated from the water phase. The chloride was not isolated but kept in the hexane solution. The purity was checked by spectrophotometry and HPLC analysis of an aliquot which had been solvolyzed in methanol. A trace of olefin but no starting material or other impurities was found. A stock solution of the substrate in hexane was kept in the freezer.

Method 2. Recrystallized alcohol (4.0 mg) dissolved in 2 mL of dichloromethane containing some $CaCl_2$ was cooled to ca. −10 °C. Dry HCl gas was bubbled through the solution for 2 min and then dry nitrogen for 1 min. The dichloromethane solution was filtered, but the product was not isolated. The purity was checked as above. The chloride is less stable in dichloromethane than in hexane. Method 2 is not good for preparing the deuteriated chloride since some H–D exchange occurs during the synthesis.

1,1-Diphenyl-1-chloro[2,2,2-$^2H_3$]ethane (d-1-Cl) was prepared as above by method 1 from **d-1-OH** but with deuteriated concentrated hydrochloric acid (Glaser, 37% DCl in D_2O, 99.5% ^2H).

(17) Guindon, Y.; Frerette, R.; Fortin, R.; Rokach, J. *J. Org. Chem.* **1983**, *48*, 1357–1359.

Kinetics and Product Studies. The reaction solutions were prepared by mixing the acetonitrile with the cosolvent at room temperature, ca. 22 °C. The reaction vessel was either a thermostated 3-mL UV cell or a 2-mL HPLC flask, sealed with a gas-tight PTFE septum, which was placed in an aluminum block in the water thermostat. The reactions were initiated by fast addition, by means of a syringe, of the substrate dissolved in hexane (**1-Cl**) or acetonitrile (all other substrates). The absorbance increases at 250 nm of the reactions were followed for at least 10 half-lives. The rate constants of the disappearance of the substrates were calculated by means of a nonlinear least-squares regression computer program. Very good pseudo-first-order behavior was seen for all of the reactions studied. The separate rate constants for the elimination and substitution reactions were obtained by combination of product composition data (from HPLC analyses), corrected for the small amount of olefin in the substrate solution, with the observed rate constants obtained as described above.

The rate constant ratios k_{12}/k_{13} for the acid-catalyzed reactions were measured after neutralizing the acidic solution after a very short reaction time with a methanolic solution of sodium hydrogen carbonate followed by analysis of the product composition by HPLC.

The rate constants of the slow acid-catalyzed solvolysis of **1-OH** in 25 vol % acetonitrile in aqueous perchloric acid were obtained from initial-rate experiments by following the increase in absorbance at 250 nm for 3% of reaction. The kinetic deuterium isotope effect was calculated as the ratio of the linear slopes (dA/dt) for the reaction of **h-1-OH** and **d-1-OH** corrected for a small difference in initial concentration of substrate measured by HPLC. The rate constants were obtained from the linear slopes and the infinity absorbance, A_∞, by the relationship $k_{obsd} = (dA/dt)/(A_\infty - dA/2)$. The infinity absorbance A_∞ was obtained from reaction of **1-OH** in acetonitrile containing 0.4 vol % 2 M aqueous sulfuric acid. Division of the rate constant for the reaction of **h-1-OH** and **d-1-OH**, respectively, gave the same isotope effect value, within experimental errors, as the division of the corrected slopes as described above. The estimated errors are considered as maximum errors derived from maximum systematic errors and random errors.

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Dimensional Analogue of a dA·dT Base Pair Devoid of Propeller Twist

Balkrishen Bhat and Nelson J. Leonard*

Contribution from the Roger Adams Laboratory, School of Chemical Sciences, University of Illinois, 1209 West California Street, Urbana, Illinois 61801-3731. *Received March 11, 1992*

Abstract: A dimensional analogue of dA·dT, with a covalently linked cross section containing a 10 π-electron core nucleus, has been synthesized from selectively protected 5-methyl-2′-deoxycytidine and 2′-deoxyadenosine. The immediate precursor, 3-(3′,5′-di-*O*-acetyl-2′-deoxy-β-D-ribofuranosyl)-9-(2′-deoxy-β-D-ribofuranosyl)-11-methyl-3*H*-pyrimido[1″,6″:1′,2′]-imidazo[4′,5′:4,5]imidazo[2,1-*i*]purin-8(9*H*)-one, with diacetyl protection on the deoxyadenosine side, has a coplanar (±0.03 Å by X-ray) central pentacyclic ring system. Selective 1,1,3,3-tetraisopropyldisiloxanediyl protection on the equivalent of the thymidine side in the analogue now permits differential phosphorylation for directed incorporation in a polydeoxyribonucleotide double helix.

Introduction

The synthesis of substituted 1,3,4,6-tetraazapentalenes,[1] with a core nucleus having 10 π-electrons, has been crucial to the construction of covalently linked cross sections with molecular architecture similar to that of hydrogen-bonded DNA/RNA base pairs for both antiparallel[2] and parallel[3] helical duplexes. These fluorescent covalently-linked cross sections, if phosphorylated and incorporated in a polydeoxynucleotide sequence,[4] for example, are capable of introducing local rigidity as a marker for potential

(1) (a) Cruickshank, K. A.; Sumoto, K.; Leonard, N. J. *Tetrahedron Lett.* **1985**, *26*, 2723. (b) Groziak, M. P.; Wilson, S. R.; Clauson, G. L.; Leonard, N. J. *J. Am. Chem. Soc.* **1986**, *108*, 8002. (c) Pereira, D. E.; Neelima; Leonard, N. J. *Tetrahedron* **1990**, *46*, 5895.

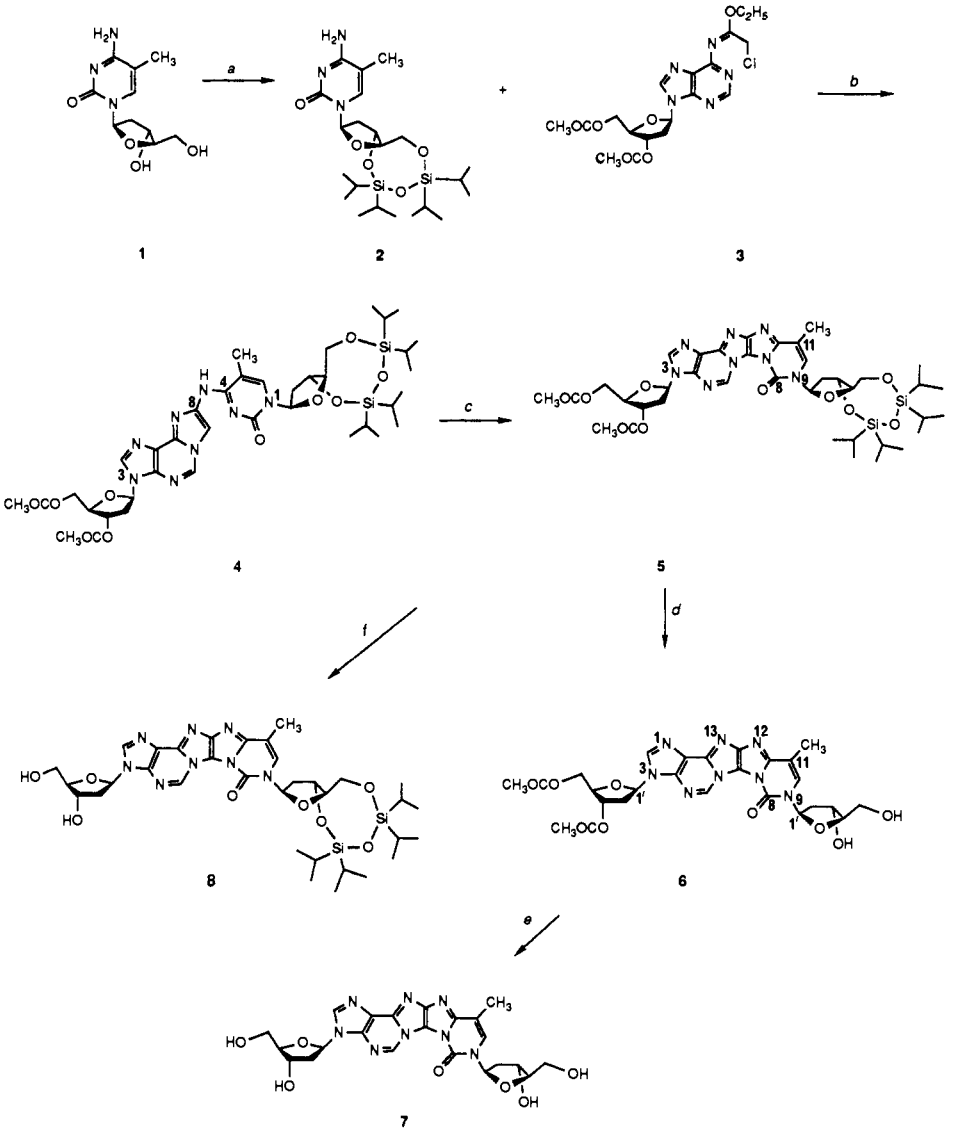
(2) (a) Devadas, B.; Leonard, N. J. *J. Am. Chem. Soc.* **1986**, *108*, 5012. (b) Leonard, N. J.; Devadas, B. *J. Am. Chem. Soc.* **1987**, *109*, 623. (c) Devadas, B.; Leonard, N. J. *J. Am. Chem. Soc.* **1990**, *112*, 3125.

(3) (a) Bhat, B.; Cruickshank, K. A.; Leonard, N. J. *J. Org. Chem.* **1989**, *54*, 2028. Leonard, N. J.; Bhat, B.; Wilson, S. R.; Cruickshank, K. A. *J. Am. Chem. Soc.* **1991**, *113*, 1398.

(4) Petrič, A.; Bhat, B.; Leonard, N. J.; Gumport, R. I. *Nucleic Acids Res.* **1991**, *19*, 585.

0002-7863/92/1514-7407$03.00/0

Scheme I



alteration in biological activity.

We have set additional goals in this investigation: (a) to use protected 5-methylcytidine in place of cytidine as the pyrimidine portion of the cross section; (b) to produce a properly substituted analogue, e.g., dA ⟒ dT,[5] that would be a closer mimic for the hydrogen-bonded base pairs, e.g., dA·dT, in the deoxyribonucleotide duplex, than anything we have produced before; (c) to provide selective protection/deprotection for the pyrimidine and purine moieties; and (d) to obtain a derivative of dA ⟒ dT that would be satisfactory for single-crystal X-ray structure determination.

Results and Discussion

For synthesis in the cytidine homologous series, 5-methyl-2′-deoxycytidine (**1**) was made by the method of Vorbrüggen and Krolikiewicz[6] and 3′,5′-*O*-protected (**2**) by the method of Markiewicz and Wiewiórowski.[7] The purpose of the 1,1,3,3-tetraisopropyldisiloxanediyl protection was to introduce selectivity into the protection/deprotection sequences (Scheme I). The purine co-reactant, compound **3**,[2] with 3′,5′-O-protection by acetyl groups was obtained in improved yield (92%) by heating 3′,5′-di-*O*-acetyl-2′-deoxyadenosine with chloroketene diethyl acetal[8] in anhydrous ethyl acetate at 70 °C for 4 h under nitrogen. Compounds **2** and **3** underwent condensation in a somewhat improved yield under these conditions to give compound **4**, in which the direction of cyclization to produce the fourth ring was shown by the downfield chemical shift of the original 8-H in **3** of δ 8.17 to 8.62 for the 5-H in **4**. The oxidative cyclization[2] of **4** to **5** was accomplished using (diacetoxyiodo)-2-nitrobenzene in the cold under argon in a solvent mixture of 1 part $(CF_3)_2C(CH_3)OH$ to 2.5 parts CH_3NO_2. The yield was improved (to 53%) by the use of freshly distilled solvents. The pentacyclic N-ring system was characterized by NMR, UV, and mass spectrometry.

Selective deprotection on the pyrimidine side of **5** was accomplished under mild conditions, i.e., stirring a solution in anhydrous tetrahydrofuran with tetrabutylammonium fluoride adsorbed on silica gel at 20 °C for 1.5 h, followed by chromatography and crystallization. More strenuous conditions diminished the yield of **6** from 82%. Deprotection on the purine side of **5** was accomplished by treatment with *tert*-butylamine in anhydrous methanol in the cold,[3b] and the chromatographed and crystallized

(5) The central symbol, ⟒, is used to represent the two fused five-membered rings as the covalent restrictor. Thus, dA ⟒ dT denotes a covalently linked cross section analogous to dA·dT.

(6) Vorbrüggen, H.; Krolikiewicz, K. In *Nucleic Acid Chemistry*; Townsend, L. B., Tipson, R. S., Eds.; John Wiley & Sons: New York, 1978; Vol. 1, p 227 and references therein.

(7) (a) Markiewicz, W. T.; Wiewiórowski, M. In *Nucleic Acid Chemistry*; Townsend, L. B., Tipson, R. S., Eds.; John Wiley & Sons: New York, 1986; Vol. 3, pp 227, 305. (b) Markiewicz, W. T. *J. Chem. Res., Synop.* **1979**, 24. (c) Markiewicz, W. T. *J. Chem. Res., Miniprint* **1979**, 181. (d) Robins, M. J.; Wilson, J. S.; Hansske, F. *J. Am. Chem. Soc.* **1983**, *105*, 4059. (e) Pankiewicz, K.; Matsuda, A.; Watanabe, K. R. *J. Org. Chem.* **1982**, *47*, 485.

(8) (a) McElvain, S. M.; Beyerstedt, F. *J. Am. Chem. Soc.* **1937**, *59*, 2266. (b) Magnani, A.; McElvain, S. M. *J. Am. Chem. Soc.* **1938**, *60*, 2210.

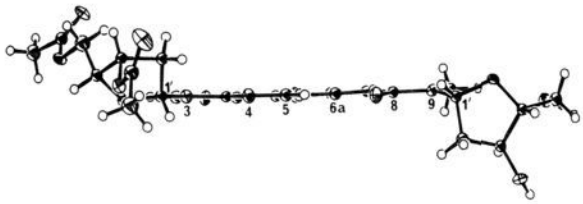


Figure 1. Single ORTEP drawing of **6** viewed from the edge of the aromatic plane, based on the X-ray crystal structure. The atoms of the central five-ring aromatic array are coplanar with a mean average deviation of ±0.03 Å.[10] Full details of the structure analysis are available from the authors upon request, e.g., positional parameters, thermal parameters, distances and angles, etc.

product **8** was obtained in 75% yield. The ^{1}H NMR assignments were complementary for **6** and **8** and were coherent with the assignments found previously in this series by analysis of proton-coupled ^{13}C NMR spectra and short- and long-range ^{1}H/^{13}C heteronuclear correlations.[2a,c] The target cross section dA ϒ dT (**7**), by name 3,9-bis(2′-deoxy-β-ribofuranosyl)-11-methyl-3*H*-pyrimido[1″,6″:1′,2′]imidazo[4′,5′:4,5]imidazo[2,1-*i*]purin-8-(9*H*)-one, was obtained in 95% yield, without the necessity of chromatographic purification, by deacetylation of **6** with *tert*-butylamine in methanol as in the conversion of **5** to **8**. The spectroscopic data were consistent throughout the series illustrated in Scheme I. In the NMR spectra, it is noteworthy that the signal for 2-H in **5** and **6**, as examples, is shifted downfield as the solvent is changed from $CDCl_3$ to $(CD_3)_2SO$. This is the most acidic hydrogen in the N-pentacyclic moiety. The 5-H and 10-H exhibit no such strong response to the solvent change.

Until this time, we have had to rely upon dimensions of a covalently linked cross section such as dA ϒ dT or A ϒ U that were calculated from a composite structure consisting of two separate domains in the formula, the 1,N^6-ethenoadenosine side and the 3,N^4-ethenocytidine side.[9] Now, we are able to provide experimentally determined dimensions for a dA ϒ dT cross section since compound **6**, 3-(3′,5′-di-*O*-acetyl-2′-deoxy-β-D-ribofuranosyl)-9-(2′-deoxy-β-D-ribofuranosyl)-11-methyl-3*H*-pyrimido[1″,6″:1′,2′]imidazo[4′,5′:4,5]imidazo[2,1-*i*]purin-8(9*H*)-one, crystallized in a form satisfactory for X-ray structure analysis.[10] The atoms of the central five-ring aromatic array are coplanar with a root mean square average deviation of ±0.03 Å (Figure 1). The torsion angles for both glycosidic linkages are in the anti range. The distance between the top two nitrogens of the central tetraazapentalene, N(13)–N(12), is 2.56 Å (we had estimated 2.6 Å[2a,c]), which may be compared with the N—H···O distance of 2.85 Å in a dA·dT Watson–Crick base pair. The distance between the bottom two nitrogens of the tetraazapentalene, N(6)—N(7), is 2.61 Å, cf. N···H—N = 2.9 Å. Thus, the closely related compound **7** is a spatial mimic of a Watson–Crick double-helical dA·dT cross section. Moreover, all of the related structures previously described as covalently linked DNA/RNA cross sections[2] are now firmly established as such by the X-ray diffraction results on compound **6**. As for the observed C1′—C1′ distance in this compound, it is 10.11 (1) Å, which is shorter than the approximate value estimated previously (10.6 Å)[4] from dimensions of the component parts. It is also shorter than the variously quoted values for the C1′—C1′ distance between hydrogen-bonded base pairs, e.g., 10.46,[11] 10.67,[11] 10.85.[12] When compound **6** is superposed on dA·dT of B DNA, A DNA, or Z DNA on exactly the same scale, as achieved by computer, there is an excellent visual overlay of the central five-ring (tetracyclic for the natural base pairs) N-heterocyclic system. It is also clear that the C1′—C1′ distance is visually shorter in **6** than in the natural dA·dT pairing (Figure 2).[13] One must therefore take into account, when regarding dA ϒ dT (**7**) as a covalently linked dimensional analogue of dA·dT, (a) the coplanarity of the central pentacyclic ring system, i.e., the absence of propeller twist; (b) the size similarity, i.e., within 0.3 Å width, of the central system; (c) the slight shortening of the C1′—C1′ distance from the normal, i.e., by ca. 0.4–0.5 Å; and (d) the absence of a proton attached to N in the core system, except under acidic pH (pK_a of **7** = 1.52 ± 0.06).

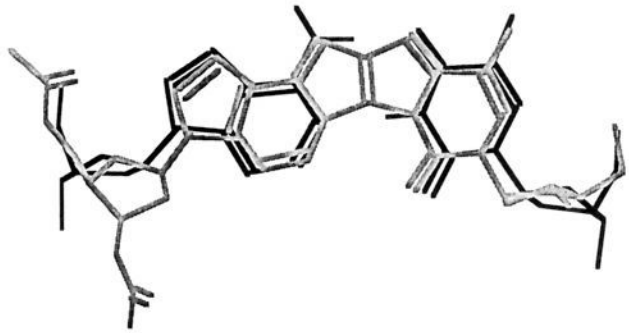


Figure 2. Superposition of the X-ray structure of **6**, $(Ac)_2$dA ϒ dT (in gray), upon that of a dA·dT base pair of B DNA (in black).[13] The diacetyldeoxyribosyl and deoxyribosyl groups and the 3′,5′-bisphosphodeoxyribosyl moieties are not involved in the superposition.

We have reported that covalent analogues of "normal", "long", and "short" C1′ to C1′ dimensions can be added to the oligodeoxyribonucleotide $d(A)_6$ with bacteriophage T4 RNA ligase.[4] While single ligation on either side of a "long" purine–purine analogue produces an identical product and the same is true for a "short" pyrimidine–pyrimidine analogue, in the case of dA ϒ dT, ligation on the pyrimidine side would produce a product different from that arising from ligation on the purine side. Now, we are in a position to determine the preferred side of T4 RNA ligase-catalyzed attachment to the "normal" analogue **7**, as the tetraphosphate, by comparison with the same reaction using the phosphates of **6** and **8** as substrates, followed by spectroscopic inspection of the products formed. Such a determination is necessary to establish the sequence of any two oligodeoxynucleotide strands that incorporate a purine–pyrimidine cross-sectional analogue as a prelude to examination of the interactions of the modified duplexes with appropriate enzymes.

Experimental Section

General. ^{1}H NMR spectra were recorded on a General Electric QE-300 spectrometer. Fast atom bombardment mass spectra (FABMS) and high-resolution mass spectra (HRFABMS) were obtained on a VG ZAB-1F instrument equipped with a high-field magnet and a VG 11/250 data system. Ultraviolet spectra were recorded on a Hewlett-Packard HP 8451A diode array spectrophotometer.

5-Methyl-2′-deoxycytidine (1). This compound was made by the method of Vorbrüggen and Krolikiewicz.[6]

5-Methyl-2′-deoxy-3′,5′-*O*-(1,1,3,3-tetraisopropyldisiloxanediyl)cytidine (2). This compound was synthesized according to the methodology reported for similar protection of cytidine, adenosine, and other nucleosides[7] and was used directly.

***N*^{4}-[3-(3′,5′-Di-*O*-acetyl-2′-deoxy-β-D-ribofuranosyl)-3*H*-imidazo-[2,1-*i*]purin-8-yl]-5-methyl-2′-deoxy-3′,5′-*O*-(1,1,3,3-tetraisopropyldisiloxanediyl)cytidine (4).** A stirred mixture of 3′,5′-di-*O*-acetyl-2′-deoxyadenosine (5 g, 14.9 mmol), chloroketene diethyl acetal[8] (4.52 g, 30 mmol), and *p*-toluenesulfonic acid (0.25 g, 1.45 mmol) in anhydrous ethyl acetate (125 mL) was heated at 70 °C under nitrogen for 4 h. When thin-layer chromatography (15% acetone/chloroform) showed complete disappearance of the starting material, the solvent was removed under reduced pressure while the bath temperature was maintained below 50 °C. The residual oil was loaded on a silica gel column and eluted with 30% ethyl acetate in chloroform. The appropriate fractions were collected and concentrated to give compound **3**[2c] as a colorless oil that was dried for 4 h under high vacuum; yield, 6 g (92%).

A mixture of **3** (6.0 g, 13.6 mmol) and 5-methyl-2′-deoxy-3′,5′-*O*-(1,1,3,3-tetraisopropyldisiloxanediyl)cytidine (**2**) (6.5 g, 13.5 mmol) in 30 mL of 1:1 benzene/acetonitrile was stirred under nitrogen at 70–75 °C for 25 h. After removal of the solvent under reduced pressure, the residue was purified by flash chromatography on silica gel, with 2–3% acetone in chloroform as eluent. Appropriate fractions were collected,

(9) Reference 2a, footnote 2.
(10) Bhat, B.; Wilson, S. R.; Leonard, N. J. *Acta Crystallogr.*, in press.
(11) Saenger, W. *Principles of Nucleic Acid Structure*; Springer-Verlag: New York, 1983; p 122.
(12) Stryer, L. *Biochemistry*, 3rd ed.; Freeman: New York, 1988; p 76.
(13) Arnott, S.; Hukins, D. W. L. *Biochem. Biophys. Res. Commun.* **1972**, *47*, 1504.

concentrated, and rechromatographed using 30% ethyl acetate in chloroform as eluent, and the product (**4**) was isolated upon evaporation as a light foam: yield, 1.5 g (14%) (yield based on unrecovered **2**, 26%); R_f 0.57 (1:1 acetone/chloroform); ^{1}H NMR ($CDCl_3$) δ 8.62 (s, 1, 5-H), 8.53 (s, 1, NH), 8.41 (s, 1, 7-H), 8.08 (s, 1, 2-H), 7.27 (s, 1, 6-H), 6.48 (dd, 1, 1′-H, J's = 6 Hz), 6.37 (dd, 1, 1″-H, J's = 5.7 Hz), 5.45–5.44 (m, 1, 3′-H), 4.60–4.53 (m, 1, 3″-H), 4.46–4.31 (m, 3, 4′-H and 5′-H's), 4.20–4.04 (m, 2, 4″-H and 5″-H_a), 3.84–3.81 (m, 1, 5″-H_b), 3.19–2.86 (m, 1, 2′-H_a), 2.72–2.54 (m, 2, 2′-H_b and 2″-H_a), 2.39–2.34 (m, 1, 2″-H_b), 2.28 (s, 3, 5-CH_3), 2.14 and 2.09 (2s, 6, $COCH_3$'s), 1.11–1.00 (m, 28, $CH(CH_3)_2$'s); UV λ_{max} (MeOH) 303 nm, 270, 222; low-resolution FAB MS m/z 841.5 (MH^+).

3-(3′,5′-Di-*O*-acetyl-2′-deoxy-β-D-ribofuranosyl)-11-methyl-9-[3′,5′-*O*-(1,1,3,3-tetraisopropyldisiloxanediyl)-2′-deoxy-β-D-ribofuranosyl]-3*H*-pyrimido[1″,6″:1′,2′]imidazo[4′,5′:4,5]imidazo[2,1-*i*]purin-8(9*H*)-one (5). To a cold (−10 °C) solution of **4** (1 g, 1.19 mmol) in a solvent mixture of 1,1,1,3,3,3-hexafluoro-2-methyl-2-propanol and nitromethane (1:2.5, 60 mL) was added (diacetoxyiodo)-2-nitrobenzene (0.5 g, 1.3 mmol) in the same solvent mixture (10 mL) under argon over a period of 1 h. After the addition of the oxidant was complete, the reaction mixture was stirred for an additional 1 h, during which time the temperature of the bath rose to −5 °C. The cooling bath was removed, and the reaction mixture was stirred for 20–30 min, when analysis by TLC in 1:1 acetone/chloroform on silica gel showed completion of the reaction. The solvent was removed carefully under vacuum using a nitrogen trap and keeping the bath temperature below 35 °C. The residual gum was triturated with toluene (15 mL), and solvent was removed under reduced pressure. The process was repeated and the product was purified by flash chromatography on silica gel using 1:1 acetone/chloroform as the eluent. The yield of **5** following drying under vacuum for 12 h was 0.53 g (53%): R_f 0.28 (1:1 acetone/chloroform); ^{1}H NMR ($CDCl_3$) δ 9.86 (s, 1, 5-H), 8.16 (s, 1, 2-H), 7.37 (s, 1, 10-H), 6.56 (dd, 1, 1′-H, J = 7.2 Hz), 6.38 (dd, 1, 1″-H, J = 6 Hz), 5.49 (m, 1, 3′-H), 4.64 (m, 1, 3″-H), 4.46–4.36 (m, 3, 4′-H and 5′-H's), 4.23–4.05 (m, 2, 4″-H and 5″-H_a), 3.89–3.86 (m, 1, 5″-H_b), 3.08–2.98 (m, 1, 2′-H_a), 2.77–2.62 (m, 2, 2′-H_b and 2″-H_a), 2.47–2.37 (m, 1, 2″-H_b), 2.41 (s, 3, 11-CH_3), 2.17 and 2.11 (2s, 6, $COCH_3$'s), 1.13–1.02 (m, 28, $CH(CH_3)_2$'s); UV λ_{max} (MeOH) 326 nm, 294, 284, 275 (sh), 254, 235; low-resolution FAB MS m/z 839.4 (MH^+).

3-(3′,5′-Di-*O*-acetyl-2′-deoxy-β-D-ribofuranosyl)-9-(2′-deoxy-β-D-ribofuranosyl)-11-methyl-3*H*-pyrimido[1″,6″:1′,2′]imidazo[4′,5′:4,5]-imidazo[2,1-*i*]purin-8(9*H*)-one (6). To a stirred solution of **5** (0.60 g, 0.71 mmol) in anhydrous tetrahydrofuran (20 mL) was added tetrabutylammonium fluoride on silica gel (1.5 g, 1.1 mmol/g of silica gel). The reaction mixture was stirred at 20 °C for 1.5 h, when the reaction was complete. The reaction mixture along with the silica gel was loaded on a silica gel column and eluted with 10%, followed by 15%, methanol in chloroform. Appropriate fractions were pooled and concentrated. Addition of acetonitrile caused the separation of compound **6** as a colorless solid which was filtered, washed with acetonitrile (2 × 10 mL), and dried under high vacuum overnight: yield of **6**, 0.35 g (82%); R_f 0.28 (15% methanol in chloroform); softens at 181 °C, mp 186–187 °C; ^{1}H NMR ($(CD_3)_2SO$) δ 9.72 (s, 1, 5-H), 8.61 (s, 1, 2-H), 7.73 (s, 1, 10-H), 6.56–6.47 (m, 2, 1′-H and 1″-H), 5.46 (m, 1, 3′-H), 5.34 (d, 1, OH, J = 3.6 Hz, ex), 5.18 (t, 1, OH, J = 4.5 Hz, ex), 4.36–4.21 (m, 4, 3″-H, 4′-H, 5′-H's), 3.90–3.85 (m, 1, 4″-H), 3.70–3.61 (m, 2, 5″-H's), 3.29–3.16 (m, 1, 2′-H_a), 2.70–2.64 (m, 1, 2″-H_a), 2.27 (bs, 5, 2′-H_b, 2″-H_b, 11-CH_3), 2.13 and 2.08 (2s, 6, $COCH_3$'s); UV λ_{max} (MeOH) 325 nm, 294, 284, 276 (sh), 253, 234; low-resolution FAB MS m/z 597.2 (MH^+); high-resolution FAB MS m/z 597.2045 ($C_{26}H_{29}N_8O_9$ requires 597.2057 amu). A crystalline sample grown from 20% methanol in aqueous acetonitrile, which separated with one molecule of acetonitrile and one of water, was subjected to X-ray analysis,[10] which fully established structure **6**.

3-(2′-Deoxy-β-D-ribofuranosyl)-11-methyl-9-[3′,5′-*O*-(1,1,3,3-tetraisopropyldisiloxanediyl)-2′-deoxy-β-D-ribofuranosyl]-3*H*-pyrimido-[1″,6″:1′,2′]imidazo[4′,5′:4,5]imidazo[2,1-*i*]purin-8(9*H*)-one (8). A mixture of **5** (0.40 g, 0.47 mmol) in 0.25 M *tert*-butylamine in anhydrous methanol (40 mL) was stirred at −5 °C for 2 h, at 0 °C for 1 h, and at room temperature for an additional 30 min. After removal of solvent under reduced pressure, the residue was coevaporated with MeOH (3 × 15 mL). Following drying for 30 min, it was purified by flash chromatography on silica gel (elution with 5–7% methanol in chloroform). Appropriate fractions were collected and concentrated, and the colorless product (**8**) was crystallized from acetonitrile: yield, 0.27 g (75%); R_f 0.38 (15% methanol in chloroform); softens at 165 °C, mp 208–209 °C; ^{1}H NMR ($(CD_3)_2SO$) δ 9.69 (s, 1, 5-H), 8.62 (s, 1, 2-H), 7.39 (s, 1, 10-H), 6.53 (dd, 1, 1′-H, J = 6.6 Hz), 6.45 (dd, 1, 1″-H, J = 5.1 Hz), 5.41 (d, 1, OH, J = 4.2 Hz, ex), 5.01 (t, 1, OH, J = 5.4 Hz, ex), 4.74–4.66 (m, 1, 3″-H), 4.46 (br s, 1, 3′-H), 4.18–3.50 (m, 6, 4′-H, 4″-H, 5′-H's, 5″-H's), 2.80–2.37 (m, 4, 2′-H's, 2″-H's), 2.27 (s, 3, 11-CH_3), 1.15–1.02 (m, 28, $CH(CH_3)_2$'s); UV λ_{max} (MeOH) 326 nm, 295, 285, 277 (sh), 236; low-resolution FAB MS m/z 755.4 (MH^+); high-resolution FAB MS m/z 755.3358 ($C_{34}H_{51}N_8O_8Si_2$ requires 755.3368 amu).

3,9-Bis(2′-deoxy-β-D-ribofuranosyl)-11-methyl-3*H*-pyrimido-[1″,6″:1′,2′]imidazo[4′,5′:4,5]imidazo[2,1-*i*]purin-8(9*H*)-one (7). This compound was obtained from **6** (0.20 g, 0.33 mmol) by the same procedure described for the preparation of **8** from **5**, except that chromatographic purification was not necessary: yield, 0.16 g (95%) of **7** as colorless crystals from methanol; mp 205–206 °C; pK_a′ 1.52 ± 0.06 (determined potentiometrically); ^{1}H NMR ($(CD_3)_2SO$) δ 9.73 (s, 1, 5-H), 8.62 (s, 1, 2-H), 7.74 (s, 1, 10-H), 6.55–6.48 (m, 2, 1′-H and 1″-H), 5.40 (d, 1, OH, J = 3.9 Hz, ex), 5.37 (d, 1, OH, J = 4.2 Hz), 5.18 (t, 1, OH, J = 4.8 Hz, ex), 5.01 (t, 1, OH, J = 5.4 Hz, ex), 4.46 (br s, 1, 3′-H), 4.36–4.34 (m, 1, 3″-H), 3.94–3.83 (m, 2, 4′-H and 4″-H), 3.75–3.47 (m, 4, 5′-H's and 5″-H's), 2.81–2.70 (m, 1, 2′-H_a), 2.46–2.24 (m, 6, 2′-H_b, 2″-H's and 11-CH_3); UV λ_{max} (MeOH) 326 nm, 295, 285, 276 (sh), 234; low-resolution FAB MS m/z 513.2 (MH^+); high-resolution FAB MS m/z 513.1857 ($C_{22}H_{25}N_8O_7$ requires 513.1846 amu).

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