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Diastereoselective addition of planar *N*-heterocycles to vinyl sulfone-modified carbohydrates: a new route to isonucleosides

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ABSTRACT

Michael-type addition reactions of planar *N*-heterocycles at the C-2 positions of vinyl sulfone-modified carbohydrates provide an efficient and general route for the carbon–*N*-heterocycle bond formation. Therefore, the addition pattern of planar heterocycles, such as imidazole, triazole, thymine, and adenine to 3-*C*-phenylsulfonyl-hex-2-enopyranosides (**1α**/**1β**) and 3-*C*-*p*-toluenesulfonyl-pent-2-enofuranosides (**2α**/**2β**) was studied for developing a general methodology for the synthesis of new classes of isonucleosides possessing a carbon–*N*-heterocycle linkage at C-2 positions of furanosyl and pyranosyl sugars. To a great extent, the anomeric configurations of the starting vinyl sulfones play crucial roles in deciding the diastereoselectivity of addition of heterocycles. However, the trityl protected 3-*C*-*p*-toluenesulfonyl-hex-2-enopyranosides (**33α**/**33β**) were judged to be more practical starting materials for desulfonylation and deprotection for the synthesis of a new class of thymine and adenine deoxyisonucleosides.

1. Introduction

In order to broaden the scope of nucleoside-based therapeutics,[1] a novel class of modified nucleosides in which nucleobases are linked to the non-anomeric carbons of carbohydrates has been designed. These 'isonucleosides' are promising therapeutic agents of apparently very low toxicity and some of them show strong and selective anti-cancer and anti-viral activities. The bond connecting the nucleobase and carbohydrate in isonucleosides has higher degree of stability toward acids and enzymatic deamination when compared to that of naturally occurring nucleosides.[2–4] Over the last few years many isonucleoside derivatives, such as *exo*-methylene-, branched-, 4′-thio-, pyranosyl, etc. have been reported to be promising therapeutic agents.[4] Although methyl 2-deoxy-2-(purin-9-yl) *arabino*furanosides and methyl 3-deoxy-3-(purin-9-yl) *xylo*-furanosides were the first isonucleosides to be synthesized[2] and biologically tested, there are only two other reports on isonucleosides comprising of *O*-methyl group at the anomeric center.[3a] Interestingly, oligonucleotides comprising of *O*-methylated deoxyanhydrohexitol nucleosides such as 1,5-anhydro-3-*O*-methyl-2-(uracil-1-yl)-2-deoxy-D-*altro*-hexitol and methyl-2-(thymin-1-yl)-2,3-dideoxy-D-*arabino*-hexopyranoside have been noted for their unique hybridization properties.[3b] In a related development, a significant number of imidazole[5] and triazole[6] nucleosides have been shown to exhibit a broad spectrum of activity against a range of viral and other diseases. However, there are only a few reports on imidazole[5g,l–n] and triazole[6b,f] nucleoside analogues possessing a carbon–*N*-heterocycle linkage at C-2 positions of the sugars.

The most common methods reported for the synthesis of isonucleosides are (a) regioselective ring opening of epoxides by nucleobases,[2,3,4a,d,e,k,q] (b) nucleophilic substitution of sulfonates derived from 1,4-anhydropentitols by nucleobases,[4h] (c) substitution of an alcohol with a base under Mitsunobu conditions,[4d,r] (d) coupling of nucleobases directly with cyclic sulfates derived from carbohydrates,[4j,n] and (e) preparation of nucleosides from aminoaldetols.[4o]

In addition to the above methods, reactions of nucleobases with activated olefins such as 2,3-dideoxy-3-nitro-hex-2-enopyranosides[4f,7] and 2,3-dideoxy-hex-2-enopyranosid-4-uloses[8] were also used as a strategy for the synthesis of isonucleosides. However, the usefulness of nitro-alkene sugars[4f,7] and hexenopyranoside uloses[6,8] as precursors for the synthesis of isonucleosides is

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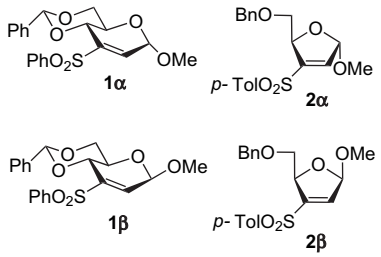


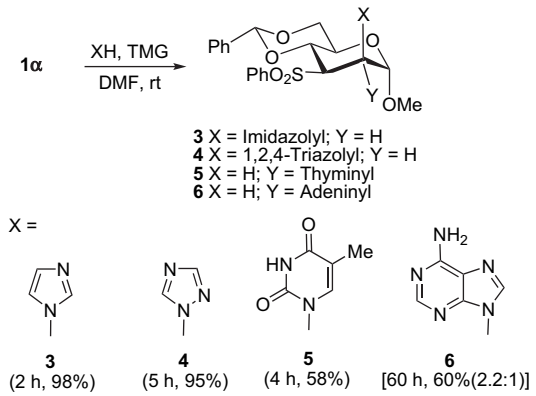
Figure 1.

reportedly limited only to pyranose systems and therefore cannot be considered as of general utility. We, on the other hand have established over the years that vinyl sulfone-modified hex-2-enopyranosides **1α**/**1β** and vinyl sulfone-modified pent-2-enofuranosides **2α**/**2β** (Fig. 1) are efficient chiral building blocks.[9] Amines[9–11] and carbon nucleophiles[9,12] added to these highly reactive Michael acceptors **1α**/**1β** and **2α**/**2β** in diastereoselective fashion and the products were obtained in excellent yields. We therefore opined that vinyl sulfone-modified carbohydrates would be useful chiral building blocks for generating new isonucleosides and biologically relevant new chemical entities when treated with imidazole and triazole. However, the directive effect of the anomeric configurations of **1α**/**1β** and **2α**/**2β** on the stereochemical outcome of these reactions was not obvious.[9] It was, therefore, necessary to study the diastereoselective addition of planar heterocycles to **1α**/**1β** and **2α**/**2β** and to establish the structures of the products unambiguously.[14] It should also be noted that the success of the proposed synthetic strategy would also depend crucially on the desulfonylation of these products at the final step.

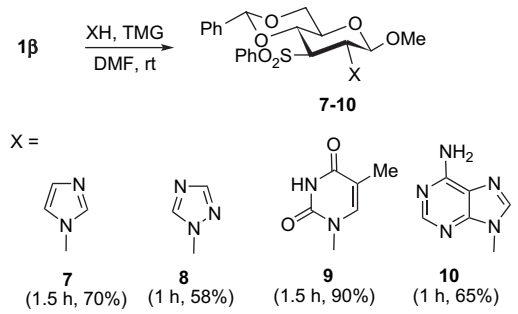
2. Results and discussion

2.1. Reactions of 1α and 1β with planar heterocycles

α-Methoxy vinyl sulfone **1α** on treatment with imidazole, 1,2,4-triazole and thymine in the presence of tetramethyl guanidine (TMG) in anhydrous DMF at ambient temperature, generated single isomers **3**, **4**, and **5**, respectively, in excellent yields (Scheme 1). Adenine, on the other hand, under similar reaction conditions afforded an inseparable mixture of two compounds in a ratio of 2.2:1. However, by comparing the spectra of the small amount of compound that crystallized out from the mixture of adenine adducts with that of **5**, the major isomer present in the reaction mixture has been assigned the structure **6** (Scheme 1). Similarly, β-vinyl sulfone **1β** was treated with imidazole, 1,2,4-triazole, thymine, and adenine in the presence of TMG in anhydrous DMF at ambient temperature to afford single isomers **7**–**10**, respectively, in moderate to good yields (Scheme 2).



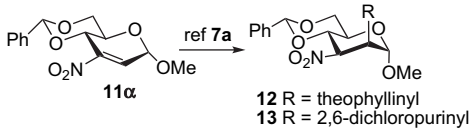
Scheme 1.



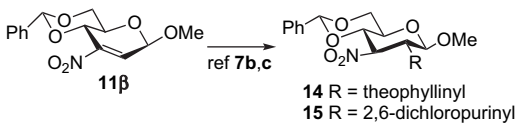
Scheme 2.

The structures of **4**, **5**, **8**, and **9** were unambiguously established by X-ray crystallography. However, it was necessary to analyze the NMR data of compounds **3**, **6**, **7**, **10** and compare the data with those of **4**, **5**, **8**, **9**. We have observed that for methyl 4,6-*O*-(phenylmethylene)-α-D-hexopyranosides with D-*allo*- and D-*gluco*-configurations, a coupling constant ($J_{1,2}$) value of 3.3–3.8 Hz implies a characteristic arrangement of equatorial H-1/axial H-2. For D-*altro*- and D-*manno*-configurations a coupling constant ($J_{1,2}$) value of 0.6–1.7 Hz is the characteristic of equatorial H-1/equatorial H-2 arrangement.[7,15g,11a,16] Hence, by comparing $J_{1,2}$ values of compounds **3** (1.0 Hz) and **4** (0 Hz) with those of the known compounds **12** (1.2 Hz) and **13** (1.2 Hz) obtained from **11α** (Scheme 3),[7a] it was concluded that compound **3** was possessing D-*manno*-configuration. On the contrary, $J_{1,2}$ values of **5** (3.4 Hz) and **6** (major isomer; 3.4 Hz) were in agreement with those of the reported compounds having D-*allo*- or D-*gluco*-configuration. Since the structure of **5** is confirmed by X-ray, the major isomer **6** was identified as a *gluco*-derivative. In the case of compounds **7**–**10**, H-1 signals appeared as doublets with relatively large coupling constant ($J_{1,2}$) values ranging between 7.3 and 7.9 Hz. Having compared $J_{1,2}$ values of the known compounds **14** (7.5 Hz) and **15** (8.0 Hz) obtained from **11β** (Scheme 4)[7b,c] with those of **7**–**10**, it was concluded that H-1 and H-2 of **7**–**10** were diaxially oriented and all isomers in β-series were assigned *gluco*-configuration. ^{13}C NMR spectra of *trans*-fused hexopyranoside derivatives have also been studied thoroughly. As per the report, on changing a substituent from equatorial to axial position at C-2, a large shielding would be expected at C-4.[17] This fact holds true in the case of **3**, **4**, and **5**. C-4 peaks of **3** and **4** (δ 74.3 and 73.9, respectively) are more shielded than that of **5** (δ 76.3). Similarly, for β-series **7**–**10**, C-4 peaks appeared between δ 75.4 and 76.6 indicating equatorial orientations of the substituents at C-2.

In a partially rigid bicyclic system like **1α** or **1β**, sterically demanding bulky phenylsulfonyl group should occupy the equatorial position after the nucleophilic addition. Interestingly though, the



Scheme 3.



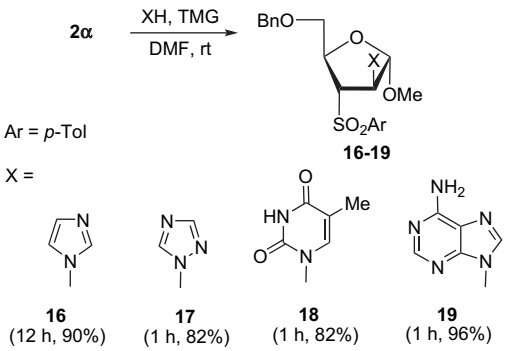
Scheme 4.

addition of *p*-toluenethiol to 1-*p*-toluenesulfonyl-cyclohexene generated the thermodynamically less stable *cis*-2-*p*-tolylmercapto-1-*p*-toluenesulfonyl-cyclohexane and not the thermodynamically more stable trans-product.[18] On the basis of reactions of **11α**/**11β** (structurally comparable to **1α**/**1β**) with several nucleophiles, a generalization can be made that the axial attack predominates over equatorial attack for **11α** and the converse is true for β-vinyl compounds **11β**.[7,15,16] However, the stereochemical course of addition of planar heterocycles to **1α** did not fully abide by this generalization. Although the addition of imidazole and 1,2,4-triazole to **1α** generated products **3** and **4**, respectively, with *manno*-configuration, the configurations at C-2 positions of thymine analogue **5** and the adenine analogue **6** (major isomer), on the contrary were surprisingly different (*gluco*-configuration) from those reported for purine adducts **12** and **13** (Scheme 3).[7a] On the basis of the reported reaction patterns of **1α** and **1β**, we propose that two factors, namely (a) stereoelectronic repulsions between incoming nucleophiles and OMe group/C_1–O_1 bond/C_1–O_5 bond and (b) stability of diequatorial (C-2, C-3) over equatorial/axial or axial/axial products would broadly decide the outcome of a reaction. In the case of *manno*-isomers **3** and **4**, we presume that the stereoelectronic repulsion caused by C_1–O_1 (OMe group) from the α-face of the sugar ring to imidazole and triazole was more important. In the case of **5** and **6**, sterically bulky thymine and adenine residues naturally preferred the equatorial dispositions. The stereochemical course of the reactions of planar heterocycles with **1α**/**1β** was further investigated using MM2 calculations. Compound **3** was found to be less stable than its C2 epimer by 0.16 kcal/mol and therefore it may be considered as a kinetic product. The kinetic product **4** was also found to be less stable than its C2 epimer by 0.48 kcal/mol. However, MM2 calculations revealed that compounds **5** and **6** were the most stable products. All other diastereomers of **3**–**6** were found to be energetically less stable. On the other hand, in the case of **1β**, the stability of triequatorial products **7**–**10** outweighed all other factors.

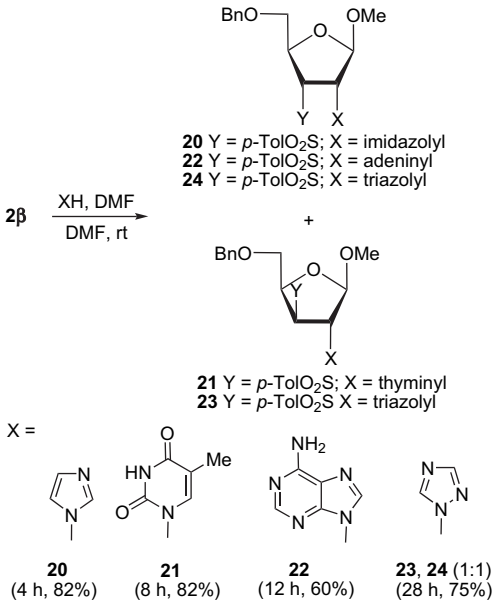
2.2. Reactions of 2α and 2β with planar heterocycles

Reactions of **2α** with imidazole, 1,2,4-triazole, thymine, and adenine in the presence of TMG in anhydrous DMF at ambient temperature yielded single isomers **16**, **17**, **18**, and **19**, respectively, in excellent yields (Scheme 5). Reactions of **2β** with imidazole, thymine, and adenine under similar conditions, afforded single isomers **20**, **21**, and **22**, respectively, in excellent to moderate yields. However, 1,2,4-triazole on reaction with **2β**, generated a mixture of two diastereomers **23** and **24** approximately in a 1:1 ratio (Scheme 6).

The products from the reactions of **2α** with planar heterocycles were expected to have *arabino*-configuration for two reasons: (a) α-methoxy group at C-1 would direct all four bulky nucleophiles to



Scheme 5.



Scheme 6.

attack the C-2 position from the β-face of the furanose ring and (b) the intermediate carbanion after the addition of a nucleophile would be protonated from the β-side of the furanose ring to push a bulky –SO_2Tol(*p*) group to the α-side of the ring. The X-ray analysis of a single crystal of **17** ($J_{1,2}$=2.0 Hz) unambiguously established the D-*arabino*-configuration. It is clearly evident from the available data that the $J_{1,2}$ values of authentic methyl α-D-*arabino*furanosides[19a,d,10b,13] range between 0 and 3.0 Hz. The $J_{1,2}$ values for authentic methyl α-D-*ribo*furanosides[17,18,10d] range between 4.0 and 4.9 Hz and the same for methyl α-D-*xylo*furanosides are always ranging between 4.0 and 4.7 Hz.[19a,c,d,20b,c,10b] Excluding the possibility of any *lyxo*-derivative formation for steric reasons, the $J_{1,2}$ values of **16**–**19**, which ranged between 0 and 2.4 Hz, surely indicated the presence of *arabino*-configuration in these molecules.

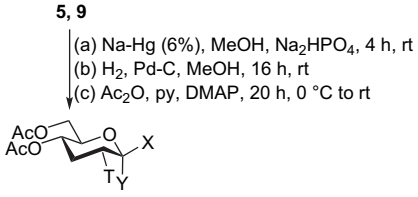
Using the similar arguments, we expected to obtain *xylo*-derivatives from the reactions between **2β** and the planar heterocycles. It has also been reported earlier that Michael addition of various nucleophiles to 3′-ene-sulfone derivatives of uridine and adenosine produced mainly the *xylo*-derivatives although in limited number of cases *ribo*-derivatives were also obtained.[21] The X-ray diffraction experiments unambiguously established **23** as a D-*xylo*-derivative and **24** as a D-*ribo*-analogue. It is reported that the $J_{1,2}$ values of authentic methyl β-D-*xylo*furanosides[19a,e,20b,c,10b] range between 0 and 2.3 Hz and those of methyl β-D-*ribo*furanosides[19a,20a,10b] are close to 0 Hz. The $J_{1,2}$ values of 5-*O*-benzyl protected methyl β-D-*arabino*-derivatives,[19a–c,e] however, range between 3.0 and 4.0 Hz. Excluding the possibility of any D-*arabino*-derivative formation on the basis of steric consideration, we have assigned D-*ribo*-configuration to **20**, **21**, and **22** ($J_{1,2}$=0 Hz for all three). Although the $J_{1,2}$ values of **21** (4.4 Hz) and **23** (3.9 Hz) were higher than those of related compounds mentioned above, it should be mentioned here that the $J_{1,2}$ values of *C*-branched D-*xylo*-furanosyl derivatives (obtained from **2β**), whose structures have been assigned unambiguously are 3.5 Hz and 3.9 Hz.[13] We, therefore, assigned D-*xylo*-configuration to **21** as well.

Diastereoselectivity of addition of nucleophiles to 2,3-dideoxy-3-*C*-nitro-pent-2-enofuranosides[22] has not been studied but there are reports on the regioselective opening of epoxides directed by the configurations at the anomeric center.[23] It has also been reported that the addition of *p*-toluenethiol to 1-*p*-toluenesulfonyl cyclopentene system generated thermodynamically more stable

trans-2-*p*-tolylmercapto-1-*p*-toluenesulfonyl cyclopentane.[24] Moreover, it has already been mentioned that the addition of various nucleophiles to 3′-ene-sulfone derivatives of nucleosides produced mainly the *xylo*-derivatives.[21] Thus, in the light of above observations it may be concluded that addition of imidazole, 1,2,4-triazole, thymine, and adenine to α-vinyl sulfone **2α** should generate products with *arabino*-configurations, which indeed was the case. On the other hand, addition of the same set of nucleophiles to β-vinyl sulfone **2β** produced two different sets of products, namely *ribo*-derivatives **20**, **22**, and **24**, and *xylo*-derivatives **21** and **23**. According to MM2 energy minimization calculations, the *ribo*-analogue **20** obtained from the reaction of **2β** with imidazole was found to be the most favorable diastereomer, whereas the triazole derivatives **23** and **24** formed in 1:1 ratio were found to be energetically almost equally favorable. Accordingly compounds **21** and **22** were found to be the most stable products. All other diastereomers of **20**–**24** were energetically less stable. The approach of all nucleophiles to C-2 was most probably directed by the stereoelectronic effect of the anomeric methoxy group. For **16**–**19**, **21**, and **23**, the trans-relationship of groups at C-2 and C-3 was also expected to follow the literature precedence discussed above.

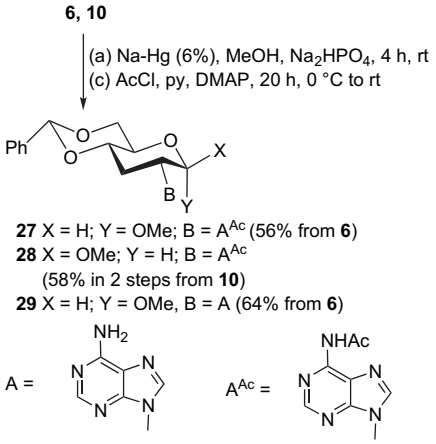
2.3. Desulfonylation leading to the synthesis of isonucleosides

Since the success of a scheme for the synthesis of deoxynucleosides using vinyl sulfone-modified carbohydrates would depend crucially on the desulfonylation step, we experimented with the most common desulfonylating agents known in the literature.[12a] The Na–Hg-mediated reduction is the most widely used radical-based method for the desulfonylation of organic molecules and has been used extensively for the desulfonylation of β-amino sulfones and γ-amino sulfone derivatives.[12] Another electron-transfer method that uses Mg metal in MeOH has also been reported with there being at least one report where Mg in MeOH was successfully used for the desulfonylation of a β-amino sulfone compound. However, attempted desulfonylation of furanosides **16**–**24** using Na–Hg, MeOH–Mg or even with our reagent[12] MeOH–Mg–$NiBr_2$ used successfully in the synthesis of furanosyl deoxyaminosugars led to extensive degradation of the starting materials. Only the pyranosides were found to be stable toward Na–Hg (6%) mediated desulfonylation reactions. Thus, the thymine derivatives **5** and **9** on treatment with Na–Hg (6%) in a buffered system underwent efficient desulfonylation. The product of the desulfonylation reaction was directly deprotected under reductive conditions and finally acetylation produced the desired isonucleosides **25** and **26** in 72% and 64% overall yields, respectively (Scheme 7). In the adenine series compound **6**, which was a mixture of epimers at C-3 and the pure compound **10** were also desulfonylated successfully with Na–Hg (6%) and the products were isolated as the acetyl derivatives **27** and **28**, respectively (Scheme 8). Since it was necessary to establish the stereochemistry at C-3 of **6** (or its desulfonylated product) we also isolated crystalline **29** because of its utility in X-ray analysis of its single crystal. However, attempted removal of



25 X = H; Y = OMe (72% in 3 steps from **5**)
26 X = OMe; Y = H (64% in 3 steps from **9**)

Scheme 7.

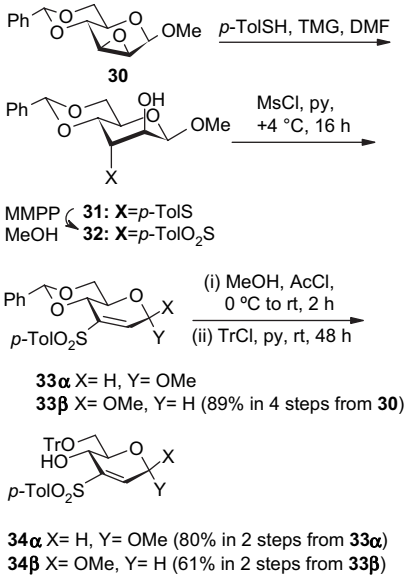


27 X = H; Y = OMe; B = A^{Ac} (56% from **6**)
28 X = OMe; Y = H; B = A^{Ac}
(58% in 2 steps from **10**)
29 X = H; Y = OMe, B = A (64% from **6**)

Scheme 8.

the phenylmethylene group of compounds **27**–**29** under acidic or reductive conditions afforded inseparable mixture of compounds. Since we were unable to remove the phenylmethylene group from compounds **27**–**29**, we designed an alternative strategy for the synthesis of adenine isonucleosides. We presumed that trityl protected vinyl sulfone-modified carbohydrates would be more useful for the synthesis of these compounds. We, therefore, converted the known[15] vinyl sulfone **33α** into the tritylated analogue **34α** in two steps in excellent overall yield (Scheme 9). The β-anomer was synthesized as follows. The known epoxide[10] **30** was treated with thiocresol in the presence of TMG to obtain the sulfide **31**. MMPP mediated oxidation of **31** afforded the sulfone **32**. The crude sulfone was mesylated and an in situ elimination of the methanesulfonate group produced **33β** in 89% overall yield. Compound **33β** was converted to the tritylated derivative **34β** in the usual way (Scheme 9).

Tritylated α-methoxy vinyl sulfone **34α** on treatment with adenine in the presence of TMG in anhydrous DMF at ambient temperature, afforded an inseparable mixture of compounds **35** in 1:1 ratio. The mixture was subjected to Na–Hg mediated desulfonylation to afford a single compound **36** proving that the sulfonylated derivatives **35** were a mixture of C-3 epimers. The trityl group of **36** was removed easily under acidic condition and the deprotected

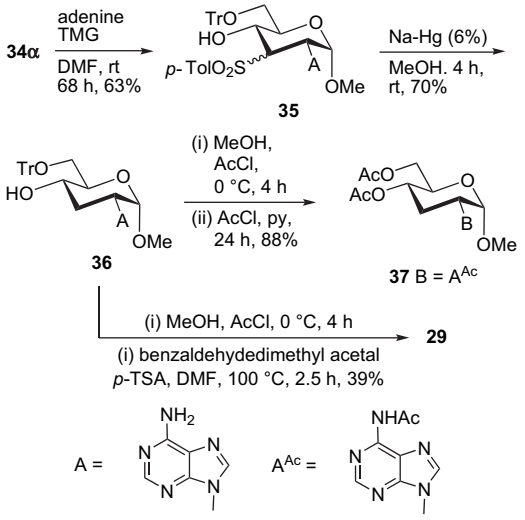


33α X= H, Y= OMe
33β X= OMe, Y= H (89% in 4 steps from **30**)

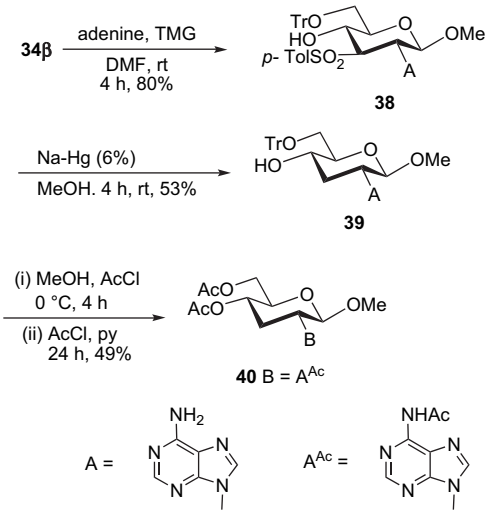
34α X= H, Y= OMe (80% in 2 steps from **33α**)
34β X= OMe, Y= H (61% in 2 steps from **33β**)

Scheme 9.

product was isolated as the peracetylated derivative **37** in 88% yield in two steps (Scheme 10). Since the structure of compound **29** was established by X-ray analysis, the trityl derivative **36** was deprotected and converted to **29** to establish the C-2′ configuration of the Michael adduct **35**. The β-methoxy vinyl sulfone **34β** (Scheme 11) under similar reaction conditions reacted with adenine to afford a single isomer **38**. Compound **38** was desulfonylated by Na–Hg to **39** in good yield. Compound **39** was detritylated under acidic condition and the product was isolated as the peracetylated derivative **40** in 49% yield in two steps (Scheme 11).[25]



Scheme 10.



Scheme 11.

3. Conclusion

We have developed a general methodology for the synthesis of several biologically relevant intermediates where planar heterocycles imidazole, triazole, thymine, and adenine are attached to the C-2 positions of both hexose and pentose systems. Since this methodology has rendered a direct access to new isonucleosides, we anticipate that other nucleobases can also be condensed readily with vinyl sulfone-modified carbohydrates. In most of the cases studied the diastereoselectivity of addition was directed by the configuration at the anomeric position but this effect was more pronounced in the case of pentofuranosyl systems. It, however, remains undecided at this stage, whether the carbohydrate ring puckering caused by the stereoelectronic properties of thymine, adenine or triazole and their probable interactions with $ArSO_2$ group are in any way responsible for the formation of *gluco*-derivatives from **1α** or *ribo*-derivatives from **2β**.[24] Although the pentofuranosyl isonucleosides underwent extensive degradation under desulfonylation conditions, the hexopyranosyl thymines were easily desulfonylated. Desulfonylated and deprotected hexopyranosyl adenines were obtained using a modified route. As a result of the present study, it was possible to synthesize several new C1-*O*-methylated 2′,3′-dideoxyhexopyranosyl nucleosides. The biological properties of this new group of isonucleosides as monomers and as oligomers will be reported elsewhere.

4. Experimental

4.1. General methods

All reactions were conducted under nitrogen atmosphere at ambient temperature. Melting points were determined in open-end capillary tubes and are uncorrected. Carbohydrates and other fine chemicals were obtained from commercial suppliers and are used without purification. Solvents were dried and distilled following the standard procedures. TLC was carried out on pre-coated silica gel plates (F_{254}) and the spots were visualized with UV light or by charring the plate dipped in 5% H_2SO_4–MeOH solution. Column chromatography was performed on silica gel (230–400 mesh). Most of the ^1H NMR spectra were recorded at 200 MHz in $CDCl_3$ using residual $CHCl_3$ as internal reference and a few were recorded at 300 MHz, 400 MHz and 500 MHz in appropriate deuterated solvent. Most of the ^{13}C NMR was recorded at 50.0 MHz in $CDCl_3$ using triplet centered at δ 77.27 as internal reference and a few were recorded at 75 MHz and 100 MHz in $CDCl_3$. DEPT experiments were carried out to identify the methylene carbons using above mentioned spectrometer. Optical rotations were recorded at 589 nm. Micro analytical data were obtained from Carlo-Erba CHNS-0 EA 1108 elemental analyzer located at the National Chemical Laboratory, Pune, India.

4.2. General procedure for the synthesis of 3, 4, 7, 8, 16, 17, 20, 23, and 24

To a well-stirred solution of imidazole or 1,2,4-triazole and TMG in anhydrous DMF (10 mL/mmol) was added appropriate vinyl sulfone-modified carbohydrate (1 equiv) and the mixture was stirred at ambient temperature. After completion of the reaction (TLC), water (1 mL) was added and the excess solvent was evaporated under reduced pressure to obtain a solid residue. The solid residue was dissolved in EtOAc and saturated $NaHCO_3$ solution was added. The aqueous layer was extracted with EtOAc (3×40 mL). The combined organic layers were dried over Na_2SO_4, filtered, and the filtrate was concentrated to dryness under reduced pressure. The crude material was purified over silica gel to obtain the title compounds.

4.3. General procedure for the synthesis of 5, 6, 9, 10, 18, 19, 21, and 22

To a well-stirred solution of the appropriate nucleobase and TMG in anhydrous DMF (10 mL/mmol) was added appropriate vinyl sulfone-modified carbohydrate (1 equiv) and the resulting mixture was stirred at ambient temperature. After completion of the reaction (TLC), the reaction mixture was diluted with EtOAc (80 mL) and undissolved solid was filtered off. The filtrate was washed with saturated $NaHCO_3$ solution and the aqueous phase was extracted

with EtOAc (3×30 mL). The combined organic extracts were dried over Na_2SO_4, filtered, and the filtrate was concentrated under reduced pressure. The crude material was purified over silica gel to obtain the title compounds.

4.4. Methyl 2,3-dideoxy-2-*C*-imidazolyl-4,6-*O*-(phenylmethylene)-3-*C*-phenylsulfonyl-α-D-*manno*pyranoside 3

Compound **1α** (0.25 g, 0.644 mmol) was reacted with imidazole (0.131 g, 1.93 mmol) in the presence of TMG (0.16 mL, 1.28 mmol) to afford a fluffy material **3** in 2 h following the general procedure described above (0.29 g, 98%). Eluent: EtOAc/petroleum ether (7:3). Decomposition point: 185 °C; $[\alpha]_D^{27}$ −18.4 (*c* 1.00, $CHCl_3$); IR (Nujol): 1379 and 1461 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 3.45 (s, 3H), 4.07–3.92 (m, 3H), 4.32 (m, 2H), 4.87 (d, 1H, *J*=1.0 Hz), 5.25 (d, 1H, *J*=3.4 Hz), 5.50 (s, 1H), 7.50–7.09 (m, 10H), 7.61 (d, 2H, *J*=7.4 Hz), and 7.94 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 55.2, 61.9, 64.6, 68.9 (CH_2), 74.3 (CH_2), 100.4, 102.3, 120.3, 126.3, 128.1, 128.6, 128.7, 129.3, 133.5, 136.1, 139.1, and 140.4; MS *m*/*z* (EI): 77 (18), 91 (24), 105 (27), 121 (100), 149 (41), 157 (23), 247 (45), and 456 (<1 M^+). Anal. Calcd for $C_{23}H_{24}N_2O_6S$: C, 60.51; H, 5.29; N, 6.13; S, 7.02. Found: C, 60.22; H, 5.59; N, 6.09; S, 7.29.

4.5. Methyl 2,3-dideoxy-4,6-*O*-(phenylmethylene)-3-*C*-phenylsulfonyl-2-*C*-(1*H*-1,2,4-triazol-1-yl)-α-D-*manno*pyranoside 4

Compound **1α** (0.2 g, 0.515 mmol) was reacted with 1,2,4-triazole (0.177 g, 2.57 mmol) in the presence of TMG (0.19 mL, 1.54 mmol) to furnish needle shaped crystal **4** in 5 h following the general procedure described above (0.22 g, 95%). Eluent: EtOAc/petroleum ether (3:7). Recrystallized from EtOAc/petroleum ether (1:3); mp: 157–158 °C; $[\alpha]_D^{26}$ −35.9 (*c* 1.01, $CHCl_3$); IR ($CHCl_3$): 1448, 1510, 1583, 1780, 2225, 2339, and 2360 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 3.45 (s, 3H), 4.11–3.87 (m, 3H), 4.30 (dd, 1H, *J*=3.9, 9.7 Hz), 4.83 (s, 1H), 4.98 (dd, 1H, *J*=8.8, 11.3 Hz), 5.42 (d, 1H, *J*=4.4 Hz), 5.60 (s, 1H), 7.35–7.12 (m, 7H), 7.48 (t, 1H, *J*=7.8 Hz), 7.63 (d, 2H, *J*=7.3 Hz), 8.04 (s, 1H), and 8.42 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 55.1, 56.9, 62.1, 65.0, 69.0 (CH_2), 73.9, 99.9, 102.2, 126.3, 128.2, 128.8, 129.3, 133.7, 136.5, 140.2, 147.0, and 152.6; MS *m*/*z* (EI): 308 (47), 316 (68), 317 (34), 334 (7), 436 (35), 386 (7), 455 (7), 456 (6), and 457 (6 M^+). Anal. Calcd for $C_{22}H_{23}O_6N_3S\cdot 2H_2O$: C, 53.54; H, 4.69; N, 8.51; S, 6.49. Found: C, 53.59; H, 4.66; N, 8.04; S, 6.88.

4.6. Methyl 2,3-dideoxy-4,6-*O*-(phenylmethylene)-3-*C*-phenylsulfonyl-2-*C*-(thymin-1-yl)-α-D-*gluco*pyranoside 5

Compound **1α** (0.2 g, 0.515 mmol) was reacted with thymine (0.454 g, 3.6 mmol) in the presence of TMG (0.32 mL, 2.57 mmol) to produce a plate shaped crystalline compound **5** in 4 h following the general procedure described above (0.15 g, 58%). Eluent: $CHCl_3$/MeOH (19:1). Recrystallized from $CHCl_3$/petroleum ether (1:3); mp: 169–170 °C; $[\alpha]_D^{26}$ −34.0 (*c* 1.12, $CHCl_3$); IR ($CHCl_3$): 1689, 2401, and 4214 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 1.93 (s, 3H), 3.40 (s, 3H), 4.07–3.68 (m, 4H), 4.25 (dd, 1H, *J*=3.9, 10.3 Hz), 4.72 (d, 1H, *J*=3.4 Hz), 5.34 (s, 1H), 5.50 (dd, 1H, *J*=3.9, 11.7 Hz), 7.53–7.23 (m, 9H), 7.80 (d, 2H, *J*=7.3 Hz), and 8.87 (br s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 12.8, 51.2, 55.7, 61.6, 62.7, 69.1 (CH_2), 76.6 (C-4), 98.1, 101.9, 110.6, 126.3, 128.3, 128.9, 129.2, 129.4, 134.2, 136.5, 138.1, 139.3, 151.7, and 163.7; MS *m*/*z* (EI): 164 (41), 207 (100), 221 (32), 267 (41), 313 (20), and 514 (<1 M^+). Anal. Calcd for $C_{25}H_{26}N_2O_8S\cdot 1.5H_2O$: C, 55.55; H, 5.21; N, 5.18; S, 5.93. Found: C, 55.48; H, 5.25; N, 5.05; S, 5.61.

4.7. Methyl 2-*C*-adenin-9-yl-2,3-dideoxy-4,6-*O*-(phenylmethylene)-3-*C*-phenylsulfonyl-α-D-*gluco*pyranosides 6

Compound **1α** (0.2 g, 0.515 mmol) was reacted with adenine (0.626 g, 4.63 mmol) in the presence of TMG (0.45 mL, 3.6 mmol) to generate a mixture of isomers in 60 h (0.16 g, 60%). Eluent: MeOH/$CHCl_3$ (1:19). A small amount of the major isomer contaminated with a small amount of minor isomer was isolated by crystallization [EtOAc/petroleum ether (1:3)]. ^1H NMR (200 MHz, $CDCl_3$; only major peaks reported): δ 3.36 (s, 3H), 3.80 (t, 1H, *J*=7.9 Hz), 4.10–3.98 (m, 2H), 4.30 (dd, 1H, *J*=3.9, 10.3 Hz), 4.50 (t, 1H, *J*=9.2 Hz), 4.79 (d, 1H, *J*=3.4 Hz), 5.41 (s, 1H), 5.47 (dd, 1H, *J*=4.0, 12.3 Hz), 5.83 (br s, 2H), 7.39–7.17 (m, 8H), 7.64 (d, 2H, *J*=7.3 Hz), 8.01 (s, 1H), and 8.42 (s, 1H).

4.8. Methyl 2,3-dideoxy-2-*C*-imidazolyl-4,6-*O*-(phenylmethylene)-3-*C*-phenylsulfonyl-β-D-*gluco*pyranoside 7

Compound **1β** (0.37 g, 0.945 mmol) was reacted with imidazole (0.193 g, 2.83 mmol) in the presence of TMG (0.23 mL, 1.89 mmol) to yield a fluffy material **7** in 1.5 h following the general procedure described above (0.3 g, 70%). Eluent: EtOAc/petroleum ether (3:1); mp: 82–83 °C; $[\alpha]_D^{26}$ −24.7 (*c* 1.01, $CHCl_3$); IR (Nujol): 1448, 1498, 2848, 2873, 2939, 2974, and 4214 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 3.35 (s, 3H), 3.66 (m, 1H), 3.86 (t, 1H, *J*=10.3 Hz), 4.02 (t, 1H, *J*=10.2 Hz), 4.22 (t, 1H, *J*=10.3 Hz), 4.38 (dd, 1H, *J*=4.8, 10.7 Hz), 4.54 (d, 1H, *J*=7.3 Hz), 4.64 (dd, 1H, *J*=7.5, 10.6 Hz), 5.51 (s, 1H), 6.93 (s, 1H), 7.03 (s, 1H), 7.45–7.25 (m, 8H), and 7.60 (m, 3H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 56.7, 57.5, 66.3, 67.5, 68.6 (CH_2), 75.4, 101.5, 103.1, 117.3, 126.1, 128.0, 128.6, 128.9, 129.1, 129.4, 133.6, 136.4, 137.7, and 140.1; MS *m*/*z* (EI): 77 (13), 91 (9), 105 (23), 149 (100), 209 (19), 239 (16), 247 (7), and 456 (<1 M^+). Anal. Calcd for $C_{23}H_{24}N_2O_6S$: C, 60.51; H, 5.29; N, 6.13; S, 7.02. Found: C, 60.43; H, 5.58; N, 6.02; S, 7.50.

4.9. Methyl 2,3-dideoxy-4,6-*O*-(phenylmethylene)-3-*C*-phenylsulfonyl-2-*C*-(1*H*-1,2,4-triazol-1-yl)-β-D-*gluco*pyranoside 8

Compound **1β** (0.097 g, 0.25 mmol) was reacted with 1,2,4-triazole (0.086 g, 1.25 mmol) in the presence of TMG (0.1 mL, 0.75 mmol) to furnish a needle shaped crystalline compound **8** in 1 h following the general procedure described above (0.07 g, 58%). Eluent: EtOAc/petroleum ether (3:7). Recrystallized from EtOAc/petroleum ether (1:3); mp: 128–129 °C; $[\alpha]_D^{26}$ −70.2 (*c* 1.12, $CHCl_3$); IR ($CHCl_3$): 1448, 1506, 2337, 2360, 2401, 2879, 2941, and 3134 cm^{-1}; ^1H NMR (500 MHz, C_6D_6): δ 2.90 (s, 3H), 3.17 (dt, 1H, *J*=4.83, 14.45 Hz), 3.41 (t, 1H, *J*=10.2 Hz), 3.95 (dd, 1H, *J*=4.87, 10.38 Hz), 4.12 (dd, 1H, *J*=9.55, 10.23 Hz), 4.48 (d,1H, *J*=7.54 Hz), 4.62 (t, 1H, *J*=10.76 Hz), 4.72 (q, 1H), 5.16 (s, 1H), 6.69 (t, 2H, *J*=7.64 Hz), 6.78 (m, 1H), 7.22–7.09 (m, 5H), 7.59 (d, 2H, *J*=7.6 Hz), 7.92 (s, 1H), and 7.95 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 57.8, 58.0, 64.5, 67.6, 68.7 (CH_2), 75.7, 101.7, 102.7, 126.2, 128.1, 128.2, 128.8, 129.2, 133.7, 136.3, 140.3, 145.8, and 152.0; MS *m*/*z* (EI): 77 (44), 81 (100), 91 (22), 150 (49), 210 (28), 316 (6), and 457 (<1 M^+). Anal. Calcd for $C_{22}H_{23}O_6N_3S\cdot 1H_2O$: C, 55.57; H, 4.87; N, 8.83; S, 6.74. Found: C, 55.45; H, 5.06; N, 8.78; S, 7.32.

4.10. Methyl 2,3-dideoxy-4,6-*O*-(phenylmethylene)-3-*C*-phenylsulfonyl-2-*C*-(thymin-1-yl)-β-D-*gluco*pyranoside 9

Compound **1β** (0.2 g, 0.515 mmol) was reacted with thymine (0.454 g, 3.6 mmol) in the presence of TMG (0.32 mL, 2.57 mmol) to generate a needle shaped crystalline compound **9** in 1.5 h following the general procedure described above (0.24 g, 90%). Eluent: $CHCl_3$/

MeOH (49:1). Recrystallized from EtOAc/petroleum ether (1:3); mp: 234–235 °C; $[\alpha]_D^{26}$ −38.0 (*c* 1.10, $CHCl_3$); IR ($CHCl_3$): 1693, 2401, 2931, 3394, and 4214 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 1.96 (s, 3H, thymine Me), 3.51 (s, 3H), 3.68 (q, 1H), 3.77 (t, 1H, *J*=10.2 Hz), 3.96 (t, 2H, *J*=9.5 Hz), 4.31 (dd, 1H, *J*=4.8, 10.2 Hz), 5.13 (d, 1H, *J*=10.2 Hz), 5.21 (d, 1H, *J*=7.3 Hz), 5.31 (s, 1H), 7.01 (d, 3H, *J*=7.3 Hz), 7.34–7.21 (m, 6H), 7.72 (d, 2H, *J*=7.7 Hz), and 9.50 (br s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 12.4, 57.8, 61.7, 63.2, 67.3, 68.8 (CH_2), 76.2, 100.2, 101.7, 110.8, 126.3, 128.1, 128.3, 129.0, 129.3, 133.8, 136.3, 140.4, 143.9, 151.1, and 164.6; MS *m*/*z* (EI): 77 (29), 91 (22), 81 (100), 207 (43), 247 (8), 313 (4), 374 (1), and 514 (<1 M^+). Anal. Calcd for $C_{25}H_{26}N_2O_8S\cdot 0.5H_2O$: C, 57.45; H, 5.20; N, 5.36; S, 6.13. Found: C, 57.36; H, 5.34; N, 5.10; S, 6.27.

4.11. Methyl 2-*C*-adenin-9-yl-2,3-dideoxy-4,6-*O*-(phenylmethylene)-3-*C*-phenylsulfonyl-β-D-*gluco*pyranoside 10

Compound **1β** (0.12 g, 0.317 mmol) was reacted with adenine (0.385 g, 2.85 mmol) in the presence of TMG (0.27 mL, 2.21 mmol) to generate an amorphous solid **10** in 1 h following the general procedure described above (0.11 g, 65%). Eluent: $CHCl_3$/MeOH (19:1); mp: 235–236 °C; $[\alpha]_D^{27}$ −38.0 (*c* 0.970, $CHCl_3$); IR (Nujol): 1608, 1676, 2678, 2754, 3284, 3350, 3564, 3616, and 3666 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 3.34 (s, 3H), 3.88 (m, 2H), 3.91 (dd, 1H, *J*=8.8, 10.2 Hz), 4.41 (dd, 1H, *J*=9.8, 15.6 Hz), 4.74 (dd, 1H, *J*=8.3, 11.2 Hz), 5.14 (d, 1H, *J*=7.9 Hz), 5.46 (t, 1H, *J*=11.2 Hz), 5.53 (s, 1H), 6.02 (br s, 2H), 7.21 (m, 4H), 7.32 (m, 4H), 7.46 (d, 2H, *J*=6.9 Hz), 7.83 (s, 1H), and 8.22 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 56.9, 57.9, 62.2, 67.9, 69.0 (CH_2), 76.2, 101.1, 101.8, 120.3, 126.4, 127.9, 128.3, 128.8, 129.4, 133.6, 136.5, 140.4, 143.0, 149.7, 152.6, and 155.8; MS *m*/*z* (EI): 77 (64), 81 (100), 91 (46), 105 (58), 136 (86), 216 (76), 247 (31), 276 (11), 322 (27), 382 (120), and 523 (4 M^+). Anal. Calcd for $C_{25}H_{25}N_5O_6S\cdot 1.5H_2O$: C, 54.54; H, 5.12; N, 12.77; S, 5.82. Found: C, 54.61; H, 5.16; N, 12.67; S, 5.98.

4.12. Methyl 5-*O*-benzyl-2,3-dideoxy-2-*C*-imidazolyl-3-*C*-*p*-toluenesulfonyl-α-D-*arabino*furanoside 16

Compound **2α** (0.23 g, 0.622 mmol) was reacted with imidazole (0.126 g, 1.86 mmol) in the presence of TMG (0.15 mL, 1.24 mmol) to afford a needle shaped crystalline compound **16** in 12 h following the general procedure described above (0.24 g, 90%). Eluent: acetone/$CHCl_3$/petroleum ether (1:1:3); mp: 158–159 °C; $[\alpha]_D^{26}$ +42.2 (*c* 1.07, $CHCl_3$); IR ($CHCl_3$): 1498, 3111, 3622, 3724, and 3757 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 2.43 (s, 3H), 3.34 (s, 3H), 3.45 (dd, 1H, *J*=2.9, 11.2 Hz), 3.88 (dd, 1H, *J*=1.5, 11.2 Hz), 4.03 (q, 1H), 4.55 (dd, 2H, *J*=12.2, 25.9 Hz), 4.72 (dt, 1H, *J*=2.0, 8.3 Hz), 4.94 (d, 1H, *J*=4.4 Hz), 4.98 (s, 1H), 6.91 (s, 2H), 7.08 (s, 1H), 7.30 (m, 7H), and 7.66 (d, 2H, *J*=7.8 Hz); ^{13}C NMR (50 MHz, $CDCl_3$): δ 21.5, 54.9, 64.7, 68.9 (CH_2), 69.5, 73.7 (CH_2), 77.6, 107.9, 116.9, 127.7, 128.3, 128.4, 130.2, 135.0, 136.3, 137.4, and 145.7; MS *m*/*z* (EI): 91 (100), 121 (6), 159 (36), 227 (52), 411 (6), and 442 (1.3 M^+). Anal. Calcd for $C_{23}H_{26}N_2O_5S$: C, 62.42; H, 5.91; N, 6.33; S, 7.24. Found: C, 62.37; H, 5.91; N, 6.07; S, 7.30.

4.13. Methyl 5-*O*-benzyl-2,3-dideoxy-3-*C*-*p*-toluenesulfonyl-2-*C*-(1*H*-1,2,4-triazol-1-yl)-α-D-*arabino*furanoside 17

Compound **2α** (0.27 g, 0.732 mmol) was reacted with 1,2,4-triazole (0.252 g, 3.66 mmol) in the presence of TMG (0.27 mL, 2.19 mmol) to produce a needle shaped crystalline compound **17** in 1 h following the general procedure described above (0.26 g, 82%). Eluent: EtOAc/petroleum ether (3:7). Recrystallized from EtOAc/petroleum ether (1:3); mp: 106–107 °C; $[\alpha]_D^{26}$ +53.3 (*c* 1.01, $CHCl_3$); IR ($CHCl_3$): 1305, 1315, 1361, 1454, 1506, 1596, 1720, and 2401 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 2.40 (s, 3H), 3.36 (s, 3H), 3.58 (dd, 1H, *J*=2.0, 11.2 Hz), 3.84 (dd, 1H, *J*=2.0, 11.2 Hz), 4.41 (dd, 1H, *J*=6.8, 13.2 Hz), 4.65 (d, 1H, *J*=11.7 Hz), 4.51 (d, 1H, *J*=12.2 Hz), 4.77 (m, 1H), 5.12 (d, 1H, *J*=2.0 Hz), 5.19 (dd, 1H, *J*=2.0, 6.4 Hz), 7.24 (d, 2H, *J*=8.3 Hz), 7.33 (s, 5H), 7.62 (d, 2H, *J*=8.3 Hz), and 7.85 (d, 2H, *J*=10.7 Hz); ^{13}C NMR (50 MHz, $CDCl_3$): δ 21.3, 55.3, 66.4, 67.0, 69.0 (CH_2), 73.3 (CH_2), 77.3, 106.6, 127.4, 128.0, 128.1, 129.8, 134.5, 137.5, 143.4, 145.5, and 152.2; MS *m*/*z* (EI): 91 (100), 122 (26), 160 (6), 228 (8), 253 (3), 337 (3), 413 (2), and 443 (2 M^+). Anal. Calcd for $C_{22}H_{25}N_3O_5S$: C, 59.58; H, 5.67; N, 9.47; S, 7.22. Found: C, 59.77; H, 5.96; N, 9.33; S, 7.71.

4.14. Methyl 5-*O*-benzyl-2,3-dideoxy-2-*C*-thymin-1-yl-3-*C*-*p*-toluenesulfonyl-α-D-*arabino*furanoside 18

Compound **2α** (0.35 g, 0.935 mmol) was reacted with thymine (0.824 g, 6.54 mmol) in the presence of TMG (0.58 mL, 4.67 mmol) to generate a fluffy mass **18** in 1 h following the general procedure described above (0.38 g, 82%). Eluent: MeOH/acetone/$CHCl_3$ (1:1:18); mp: 65–67 °C; $[\alpha]_D^{25}$ +21.0 (*c* 1.09, $CHCl_3$); IR ($CHCl_3$): 1377, 1458, 1596, 1689, 2401, 2871, 2929, 3218, 3392, and 4214 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 1.51 (s, 3H), 2.43 (s, 3H), 3.26 (s, 3H), 3.74 (dd, 1H, *J*=2.9, 11.2 Hz), 3.97 (dd, 1H, *J*=2.0, 10.8 Hz), 4.16 (q, 1H), 4.59 (m, 3H), 4.90 (s, 1H), 5.39 (d, 1H, *J*=6.8 Hz), 7.13 (s, 1H), 7.32 (m, 7H), 7.80 (d, 2H, *J*=8.3 Hz), and 9.13 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 12.0, 21.7, 55.1, 63.4, 67.0, 69.6 (CH_2), 74.0 (CH_2), 77.6, 106.9, 112.3, 128.0, 128.7, 129.1, 130.2, 134.7, 137.4, 137.7, 145.8, 150.3, and 163.6; MS *m*/*z* (EI): 91 (100), 65 with <1%, 79, 217, 285, 379, 468, and 500 (M^+). Anal. Calcd for $C_{25}H_{28}N_2O_7S$: C, 59.97; H, 5.63; N, 5.59; S, 6.40. Found: C, 59.54; H, 5.29; N, 5.20; S, 7.06.

4.15. Methyl 2-*C*-adenin-9-yl-5-*O*-benzyl-2,3-dideoxy-3-*C*-*p*-toluenesulfonyl-α-D-*arabino*furanoside 19

Compound **2α** (0.31 g, 0.82 mmol) was reacted with adenine (0.997 g, 7.38 mmol) in the presence of TMG (0.72 mL, 5.74 mmol) to yield to an amorphous solid **19** in 1 h following the general procedure described above (0.4 g, 96%). Eluent: MeOH/acetone/$CHCl_3$ (1:2:97); mp: 61–63 °C; $[\alpha]_D^{25}$ +45.0 (*c* 1.09, $CHCl_3$); IR ($CHCl_3$): 1473, 1596, 1639, 2401, 2869, 2927, 3176, 3355, 3409, 3481, and 4214 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 2.31 (s, 3H), 3.34 (s, 3H), 3.75 (dd, 1H, *J*=2.4, 11.3 Hz), 3.98 (dd, 1H, *J*=1.5, 11.3 Hz), 4.64 (dd, 2H, *J*=11.4, 28.3 Hz), 4.85–4.72 (m, 2H), 5.12 (d, 1H, *J*=2.4 Hz), 5.37 (dd, 1H, *J*=2.5, 6.4 Hz), 5.98 (br s, 2H), 7.11 (d, 2H, *J*=7.9 Hz), 7.37 (m, 5H), 7.60 (d, 2H, *J*=8.3 Hz), 7.82 (s, 1H), and 8.23 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 21.5, 55.7, 62.4, 66.1, 69.6 (CH_2), 73.8 (CH_2), 77.3, 106.8, 119.5, 127.7, 127.9, 128.3, 128.5, 129.7, 134.6, 137.8, 139.3, 145.4, 149.3, 152.9, and 155.8; MS *m*/*z* (EI): 91 (100), 136 (14), 188 (21), 219 (14), 294 (18), 354 (1.6), 403 (1.3), 418 (1.8), 478 (1), and 509 (<1 M^+). Anal. Calcd for $C_{25}H_{27}N_5O_5S$: C, 58.92; H, 5.33; N, 13.74; S, 6.29. Found: C, 59.06; H, 5.39; N, 13.77; S, 7.10.

4.16. Methyl 5-*O*-benzyl-2,3-dideoxy-2-*C*-imidazolyl-3-*C*-*p*-toluenesulfonyl-β-D-*ribo*furanoside 20

Compound **2β** (0.39 g, 1.04 mmol) was reacted with imidazole (0.212 g, 3.12 mmol) in the presence of TMG (0.26 mL, 2.08 mmol) to afford a cotton like crystalline **20** in 4 h following the general procedure described above (0.38 g, 82%). Eluent: acetone/$CHCl_3$/petroleum ether (1:1:3). Recrystallized from $CHCl_3$/petroleum ether (1:3); mp: 128–129 °C; $[\alpha]_D^{26}$ −1.3 (*c* 1.12, $CHCl_3$); IR ($CHCl_3$): 1596, 2341, 2360, 2401, 2866, 2933, 2966, and 4214 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 2.08 (br hump, 1H), 2.42 (s, 3H), 3.30 (s, 3H), 3.34 (m, 1H), 3.59 (dd, 1H, *J*=2.0, 10.7 Hz), 4.26 (q, 1H), 4.46 (dd, 2H, *J*=12.2, 14.6 Hz), 4.79 (m, 1H), 4.88 (d, 1H, *J*=5.9 Hz), 4.96 (s, 1H), 7.00 (d, 2H, *J*=11.2 Hz), and 7.33 (m, 9H); ^{13}C NMR (50 MHz, $CDCl_3$):

δ 21.7, 54.6, 62.7, 65.0, 71.6 (CH_2), 73.3 (CH_2), 78.3, 106.9 (C-1), 127.6, 127.8, 128.1, 128.4, 130.0, 135.2, 137.6, and 145.5; MS *m*/*z* (EI): 91 (100), 121 (6), 159 (10), 227 (18), and 442 (3 M^+). Anal. Calcd for $C_{23}H_{26}N_2O_5S$: C, 62.42; H, 5.91; N, 6.33; S, 7.24. Found: C, 62.49; H, 6.12; N, 6.34; S, 7.56.

4.17. Methyl 5-*O*-benzyl-2,3-dideoxy-2-*C*-(thymin-1-yl)-3-*C*-*p*-toluenesulfonyl-β-D-*xylo*furanoside 21

Compound **2β** (0.24 g, 0.641 mmol) was reacted with thymine (0.565 g, 4.48 mmol) in the presence of TMG (0.4 mL, 3.205 mmol) to generate an amorphous solid **21** in 8 h following the general procedure described above (0.26 g, 82%). Eluent: $CHCl_3$/MeOH (99:1); mp: 80–81 °C; $[\alpha]_D^{25}$ −44.0 (*c* 1.12, $CHCl_3$); IR ($CHCl_3$): 1465, 1596, 1691, 2343, 2360, 2401, 2931, 3392, 3629, 3678, and 4214 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$): δ 1.63 (s, 3H), 2.41 (s, 3H), 3.31 (s, 3H), 3.74 (dd, 1H, *J*=4.4, 10.3 Hz), 3.87 (dd, 1H, *J*=2.2, 10.3 Hz), 4.04 (q, 1H), 4.66 (dd, 2H, *J*=12.1, 18.7 Hz), 4.77 (m, 1H), 4.91 (d, 1H, *J*=4.4 Hz), 5.56 (dd, 1H, *J*=4.7, 10.6 Hz), 6.83 (s, 1H), 7.38 (m, 7H), 7.69 (d, 2H, *J*=8.1 Hz), and 8.81 (br s, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 12.3, 21.7, 55.3, 57.2, 63.2, 71.9 (CH_2), 73.6 (CH_2), 76.3, 101.4, 110.2, 127.7, 127.9, 128.6, 128.7, 130.2, 134.3, 137.2, 138.0, 146.2, 151.2, and 163.4; MS *m*/*z* (EI): 91 (100), 217 (12), 285 (6), 333 (3), 379 (2), 468 (6), and 500 (6 M^+). Anal. Calcd for $C_{25}H_{28}N_2O_7S\cdot 1H_2O$: C, 57.89; H, 5.82; N, 5.40; S, 6.18. Found: C, 57.74; H, 5.52; N, 5.38; S, 6.86.

4.18. Methyl 2-*C*-adenin-9-yl-5-*O*-benzyl-2,3-dideoxy-3-*C*-*p*-toluenesulfonyl-β-D-*ribo*furanoside 22

Compound **2β** (0.38 g, 1.01 mmol) was reacted with adenine (1.22 g, 9.09 mmol) in the presence of TMG (0.88 mL, 7.07 mmol) to generate an amorphous solid **22** in 12 h following the general procedure described above (0.31 g, 60%). Eluent: MeOH/acetone/$CHCl_3$ (1:2:97); mp: 196–198 °C; $[\alpha]_D^{25}$ +27.0 (*c* 1.01, $CHCl_3$); IR (Nujol): 1579, 1598, 1658, 3159, 3274, 3338, and 3390 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 2.36 (s, 3H), 3.35 (s, 3H), 3.56 (dd, 1H, *J*=6.3, 10.7 Hz), 3.69 (dd, 1H, *J*=2.9, 10.8 Hz), 4.35 (t, 1H, *J*=7.3 Hz), 4.58 (dd, 2H, *J*=12.3, 17.6 Hz), 5.14 (s, 1H), 5.18 (m, 1H), 5.40 (d, 1H, *J*=5.4 Hz), 5.95 (br s, 2H), 7.08 (d, 2H, *J*=8.3 Hz), 7.37 (m, 7H), 7.99 (s, 1H), and 8.20 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 21.8, 55.4, 58.7, 64.5, 72.7 (CH_2), 73.7 (CH_2), 78.2, 107.4 (C-1), 119.5, 128.0, 128.7, 130.0, 135.2, 137.9, 140.0, 145.7, 150.6, 153.1, and 155.7; MS *m*/*z* (EI): 91 (100), 136 (22), 154 (3), 188 (4), 219 (6), and 354 (4). Anal. Calcd for $C_{25}H_{27}N_5O_5S$: C, 58.92; H, 5.33; N, 13.74; S, 6.29. Found: C, 59.44; H, 5.19; N, 13.13; S, 6.58.

4.19. Methyl 5-*O*-benzyl-2,3-dideoxy-3-*C*-*p*-toluenesulfonyl-2-*C*-(1*H*-1,2,4-triazol-1-yl)-β-D-*xylo*furanoside 23 and methyl 5-*O*-benzyl-2,3-dideoxy-3-*C*-*p*-toluenesulfonyl-2-*C*-(1*H*-1,2,4-triazol-1-yl)-β-D-*ribo*furanoside 24

Compound **2β** (0.27 g, 0.732 mmol) was reacted with 1,2,4-triazole (0.252 g, 3.66 mmol) in the presence of TMG (0.27 mL, 2.19 mmol) to produce the mixture of **23** and **24** in 28 h following the general procedure described above (0.22 g, 75%). Eluent: EtOAc/petroleum ether (3:7). Compound **23**: isolated yield: 0.08 g; mp: 179–180 °C; $[\alpha]_D^{26}$ −5.0 (*c* 1.06, $CHCl_3$); IR ($CHCl_3$): 1452, 1504, 1596, 1753, 2341, 2360, 2399, 3620, 3681, 3786, and 4214 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 2.37 (s, 3H), 3.40 (s, 3H), 4.11 (m, 2H), 4.68 (s, 3H), 4.92 (dt, 1H, *J*=3.4, 8.05 Hz), 5.05 (d, 1H, *J*=3.9 Hz), 5.17 (dd, 1H, *J*=3.6, 9.0 Hz), 7.16 (d, 2H, *J*=8.3 Hz), 7.36 (m, 5H), 7.49 (d, 2H, *J*=8.3 Hz), 7.65 (s, 1H), and 7.76 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 21.7, 56.7, 66.3, 67.4, 69.8 (CH_2), 73.7 (CH_2), 78.9, 108.1, 127.7, 128.0, 128.5, 130.1, 135.7, 138.1, 144.2, 145.7, and 152.8; MS *m*/*z* (EI): 91 (100), 228 (6), 255 (11), 412 (9), and 443 (6 M^+). Anal. Calcd for $C_{22}H_{25}N_3O_5S$: C, 59.58; H, 5.67; N, 9.47; S, 7.22. Found: C, 59.92; H, 5.29; N, 9.36; S, 7.45. Compound **24**: isolated yield: 0.02 g (separated by recrystallization). Recrystallized from EtOAc/petroleum ether (1:4); mp: 82–83 °C; $[\alpha]_D^{26}$ +13.7 (*c* 1.00, $CHCl_3$); IR ($CHCl_3$): 1425, 1502, 1527, 1598, 2360, 2399, 2432, 3629, 3681, and 4214 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 2.44 (s, 3H), 3.34 (s, 3H), 3.38–3.26 (m, 1H), 3.72 (dd, 1H, *J*=1.5, 11.3 Hz), 4.42 (dd, 3H, *J*=12.2, 22.4 Hz), 4.75 (m, 1H), 5.08 (s, 1H), 5.14 (d, 1H, *J*=5.9 Hz), 7.36–7.25 (m, 7H), 7.54 (d, 2H, *J*=8.3 Hz), 7.92 (s, 1H), and 8.25 (s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 21.9, 54.9, 64.1, 65.4, 70.8 (CH_2), 73.6 (CH_2), 78.9, 106.2, 127.7, 128.0, 128.6, 130.2, 135.9, 138.1, 145.8, and 152.2; MS *m*/*z* (EI): 91 (100), 122 (10), 228 (25), 253 (12), 337 (7), and 443 (10, M^+). Anal. Calcd for $C_{22}H_{25}N_3O_5S$: C, 59.58; H, 5.67; N, 9.47; S, 7.22. Found: C, 59.48; H, 5.64; N, 9.66; S, 7.69.

4.20. Methyl 2,3-dideoxy-4,6-di-*O*-acetyl-2-*C*-(thymin-1-yl)-α-D-*gluco*pyranoside 25

To a well-stirred solution of **5** (0.25 g, 0.49 mmol) and Na_2HPO_4 (0.55 g, 4 mmol) in anhydrous MeOH (10 mL) was added Na–Hg (~6%, 15.8 g) and the resulting mixture was stirred at ambient temperature under N_2 atmosphere. After 4 h (TLC) the reaction mixture was diluted with EtOAc (40 mL) and undissolved solid was filtered off by passing through a Celite bed. The filtrate was evaporated under reduced pressure. The crude residue was triturated in EtOAc and the organic layer was washed with saturated $NaHCO_3$ solution (3×30 mL). The organic layer was separated, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The crude material was purified over silica gel to afford a white solid. The solid thus obtained was dissolved in anhydrous MeOH containing AcOH (MeOH/AcOH=80:1) and N_2 gas was bubbled for 15 min to remove dissolved oxygen. Pd–C (10%, 0.02 g) was added to this solution and debenzyledination was complete in 12 h at ambient temperature under H_2 atmosphere. The reaction mixture was filtered through Celite and the Celite bed was thoroughly washed with warm MeOH. The filtrate was evaporated under reduced pressure to obtain a jelly material, which was dissolved in anhydrous pyridine (10 mL). The resulting solution was cooled to 0 °C. Acetic anhydride (0.2 mL, 2.11 mmol) was added dropwise to this solution with stirring and the reaction mixture was allowed to attain room temperature. Stirring was continued overnight until TLC showed completion of the reaction. The solvent was then co-evaporated three times with a mixture of methanol and toluene (1:3). The residue thus obtained was triturated in EtOAc (50 mL) and the organic layer was washed with saturated $NaHCO_3$ solution (3×30 mL). The organic layer was separated, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The crude material was purified over silica gel to furnish a glassy solid **25** (0.13 g, 72%). Eluent: EtOAc/petroleum ether (7:3); R_f (2% MeOH/DCM) 0.33; $[\alpha]_D^{27}$ +122.9 (*c* 0.676, $CHCl_3$); IR (KBr): 1372, 1468, 1650, 1681, 1696 and 1736 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.89 (s, 3H), 2.04 (s, 3H), 2.09 (s, 3H), 2.15–2.20 (m, 2H), 3.38 (s, 3H), 3.86–3.93 (m, 1H), 4.13–4.23 (m, 2H), 4.71 (d, 1H, *J*=3.1 Hz), 4.86–4.96 (m, 2H), 7.17 (d, 1H, *J*=0.6 Hz), 9.53 (br s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 12.4, 20.6, 20.7, 28.5 (CH_2), 50.8, 55.1, 62.2 (CH_2), 66.6, 67.8, 96.5, 110.1, 137.5, 151.3, 163.8, 169.4, 170.7; HRMS (ES^+), *m*/*z* calcd for $(M+H)^+$ $C_{16}H_{23}N_2O_8$: 371.1454. Found: 371.1449.

4.21. Methyl 2,3-dideoxy-4,6-di-*O*-acetyl-2-*C*-(thymin-1-yl)-β-D-*gluco*pyranoside 26

Compound **9** (0.25 g, 0.49 mmol) was converted to a hygroscopic solid **26** (0.116 g, 64%) following the procedure described for the preparation of **25**. Eluent: EtOAc/petroleum ether (7:3); R_f (2% MeOH/DCM) 0.4. $[\alpha]_D^{27}$ −28.4 (*c* 0.676, $CHCl_3$); IR (KBr): 1375, 1466,

1656, 1688, 1701, and 1743 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ 1.89 (s, 3H), 2.04 (s, 3H), 2.08 (s, 3H), 2.34–2.53 (m, 2H), 3.47 (s, 3H), 3.75–3.83 (m, 2H), 4.21–4.25 (m, 2H), 4.74–4.79 (m, 1H), 5.07 (d, 1H, J=7.95 Hz), 6.87 (d, 1H, J=1.14 Hz), 8.99 (br s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 12.3, 20.7, 20.8, 31.1 (CH_2), 56.8, 60.8, 62.5 (CH_2), 66.7, 74.9, 100.8, 110.8, 140.7, 150.8, 164.2, 169.8, 170.8; HRMS (ES^+), m/z calcd for $(M+H)^+$ $C_{16}H_{23}N_2O_8$: 371.1454. Found: 371.1446.

4.22. Methyl 2-*C*-(*N*-acetyl-adenin-9-yl)-2,3-dideoxy-4,6-*O*-(phenylmethylene)-α-D-*gluco*pyranoside 27

Compound **6** (0.24 g, 0.46 mmol) was desulfonylated with Na–Hg (~6%, 15 g) as described above, in anhydrous MeOH (20 mL) in the presence of Na_2HPO_4 (0.6 g, 4.2 mmol) in 4 h at ambient temperature to obtain a white solid. To a well-stirred solution of the crude solid in anhydrous pyridine (20 mL) was added a catalytic amount of DMAP (10 mg). Acetyl chloride (0.1 mL, 1.40 mmol) was added into the reaction mixture at 0 °C under N_2 atmosphere. The reaction mixture was slowly allowed to attain room temperature and stirring was continued overnight until TLC showed completion of the reaction. The excess solvent was evaporated under reduced pressure and the crude residue was co-evaporated with a mixture of methanol and toluene (1:3) to remove residual pyridine completely. Crude material thus obtained was dissolved in EtOAc (40 mL) and the organic layer was washed with saturated $NaHCO_3$ solution (3×30 mL), dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure to afford a residue. The residue was purified over silica gel to obtain a hygroscopic solid **27** (0.11 g, 56%). Eluent: EtOAc/petroleum ether (7:3); $[\alpha]_D^{27}$ +45.4 (*c* 0.71, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 2.17–2.41 (m, 2H), 2.62 (s, 3H), 3.38 (s, 3H), 3.79–4.04 (m, 3H), 4.31–4.38 (m, 1H), 4.83 (d, 1H, J=3.28 Hz), 5.04–5.14 (m, 1H), 5.61 (s, 1H), 7.37–7.52 (m, 5H), 8.18 (s, 1H), 8.60 (br s, 1H), 8.67 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 25.6, 30.4 (CH_2), 51.9, 55.2, 64.2, 69.2 (CH_2), 76.4, 97.1, 102.0, 121.2, 126.2, 128.4, 129.3, 137.1, 142.4, 149.3, 151.3, 152.3, 170.7; HRMS (ES^+), m/z calcd for $(M+Na)^+$ $C_{21}H_{23}N_5O_5Na$: 448.1597. Found: 448.1596.

4.23. Methyl 2-*C*-(*N*-acetyl-adenin-9-yl)-2,3-dideoxy-4,6-*O*-(phenylmethylene)-β-D-*gluco*pyranoside 28

Compound **10** (0.30 g, 0.57 mmol) was converted to a hygroscopic solid material **28** (0.14 g, 58%) in 48 h following the procedure described above for the preparation of **27**. Eluent: EtOAc/petroleum ether (4:1); $[\alpha]_D^{27}$ −2.1 (*c* 0.55, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 2.41–2.52 (m, 1H), 2.61 (s, 3H), 2.92–3.14 (m, 1H), 3.34 (s, 3H), 3.72–3.89 (m, 3H), 4.39–4.47 (m, 2H), 5.14 (d, 1H, J=8.17 Hz), 5.59 (s, 1H), 7.35–7.52 (m, 5H), 7.96 (s, 1H), 8.66 (s, 1H), 9.28 (br s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 25.7, 32.8 (CH_2), 56.8, 57.1, 68.9 (CH_2), 70.4, 76.2, 101.7, 101.8, 122.2, 126.1, 128.3, 129.2, 137.0, 142.9, 149.4, 151.3 (C), 152.0, 170.8; HRMS (ES^+), m/z calcd for $(M+H)^+$ $C_{21}H_{24}N_5O_5$: 426.1777. Found: 426.1778.

4.24. Methyl 2-*C*-(adenin-9-yl)-2,3-dideoxy-4,6-*O*-(phenylmethylene)-α-D-*gluco*pyranoside 29

Compound **6** (0.24 g, 0.46 mmol) was desulfonylated with Na–Hg (~6%, 15 g) in anhydrous MeOH (20 mL) in the presence of Na_2HPO_4 (0.6 g, 4.2 mmol) in 4 h at ambient temperature to produce a white solid **29** (0.11 g, 64%). Mp: 103–104 °C; $[\alpha]_D^{28}$ +32.6 (*c* 0.71, $CDCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 2.30–2.60 (m, 2H), 3.36 (s, 3H), 3.75–3.96 (m, 3H), 4.29–4.35 (m, 1H), 4.81 (d, 1H, J=3.3 Hz), 4.96–5.07 (m, 1H), 5.59 (s, 1H), 5.70 (br s, 2H), 7.32–7.51 (m, 5H), 8.00 (s, 1H), and 8.33 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 30.4 (CH_2), 51.7, 55.2, 64.2, 69.2 (CH_2), 76.7, 97.2, 101.9, 118.9, 126.1, 128.3, 129.2, 137.1, 139.8, 149.8, 153.0, 155.5; HRMS (ES^+), m/z calcd for $(M+H)^+$ $C_{19}H_{22}N_5O_4$: 384.1672. Found: 384.1679.

4.25. Methyl 2,3-dideoxy-4,6-*O*-(phenylmethylene)-3-*C*-*p*-toluenesulfonyl-β-D-*erythro*-hex-2-enopyranoside 33β

To a well-stirred solution of **30** (3.2 g, 12.1 mmol) in anhydrous DMF (15 mL) were added thiocresol (7.51 g, 60.6 mmol) and TMG (4.56 g, 36.36 mmol) under N_2 atmosphere. The resulting reaction mixture was heated at 80–90 °C for 3 h and allowed to attain room temperature. Brine solution (80 mL) was added into it. The mixture was extracted with EtOAc (3×30 mL). Combined organic layers were washed with saturated $NaHCO_3$ (2×25 mL), dried over Na_2SO_4, and filtered. The filtrate was evaporated under reduced pressure to furnish a syrupy material. The crude syrup was purified over silica gel using petroleum ether/EtOAc (3:1) as the eluent to yield **31** (4.42 g, 94%). To a solution of **31** (4.20 g, 10.82 mmol) in MeOH (30 mL) was added MMPP (16.88 g, 34.17 mmol). The reaction mixture was stirred for 6 h at ambient temperature and filtered. The filtrate was evaporated under reduced pressure to afford a crude residue. The crude material was neutralized with saturated $NaHCO_3$ (70 mL). The mixture was extracted with EtOAc (3×30 mL). Combined organic layers were dried over Na_2SO_4, filtered, and the filtrate was concentrated to dryness under reduced pressure to yield **32** quantitatively. To a solution of **32** in anhydrous pyridine (25 mL) was added a solution of methanesulfonyl chloride (2.8 mL, 36.45 mmol) in anhydrous pyridine (15 mL) at 0 °C. The reaction mixture was left overnight at 4 °C. The reaction mixture was poured into saturated $NaHCO_3$ (70 mL) and filtered through a Celite bed. The filtrate was extracted with dichloromethane (3×30 mL) and the organic extracts were collected together, dried over Na_2SO_4, and filtered. DBU (3.4 mL, 22.78 mmol) was added to the filtrate and after 5 min the solvent was evaporated under reduced pressure. The resulting residue was purified over silica gel to yield a colorless jelly **33β** (4.03 g, 88%; four steps from epoxide **30**). Eluent: with EtOAc/petroleum ether (2:3); R_f (40% EtOAc/petroleum ether) 0.33; $[\alpha]_D^{28}$ −8.2 (c 0.75, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$): δ 2.34 (s, 3H), 3.50 (s, 3H), 3.67–3.73 (m, 1H), 3.78–3.89 (m, 1H), 4.24–4.28 (m, 1H), 4.56–4.59 (m, 1H), 5.41 (d, 1H, J=1.2 Hz), 5.53 (s, 1H), 6.89 (s, 1H), 7.11 (d, 2H, J=8.0 Hz), 7.22–7.38 (m, 5H), and 7.68 (d, 2H, J=8.0 Hz); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.7, 55.8, 68.6 (CH_2), 69.8, 73.72, 98.8, 102.1, 126.3, 128.1, 128.9, 129.2, 129.4, 136.5, 136.7, 136.8, 143.1, and 144.6; HRMS (ES^+), m/z calcd for $(M+H)^+$ $C_{21}H_{23}O_6S$: 403.1215. Found: 403.1214.

4.26. Methyl 2,3-dideoxy-3-*C*-*p*-toluenesulfonyl-6-*O*-trityl-α-D-*erythro*-hex-2-enopyranoside 34α

To a well-stirred solution of compound **33α** (0.5 g, 1.24 mmol) in anhydrous MeOH (20 mL) was added acetyl chloride (0.2 mL, 2.82 mmol) dropwise at 0 °C under N_2 atmosphere over a period of 0.5 h. The resulting solution was stirred at room temperature. After 2.5 h (TLC) the solution was evaporated to dryness under reduced pressure and the residual liquid was co-evaporated twice with pyridine to obtain a syrupy compound. The compound thus obtained was dissolved in EtOAc, washed thoroughly with saturated $NaHCO_3$ solution, dried over Na_2SO_4, and filtered. The filtrate was evaporated under reduced pressure to obtain a crude mass. The crude mass was purified over silica gel with petroleum ether/EtOAc mixture (3:1) as eluent to generate a colorless jelly compound. To a solution of this compound (1.8 g, 5.73 mmol) in anhydrous pyridine (40 mL) was added trityl chloride (3.5 g, 12.55 mmol) and the resulting solution was stirred at ambient temperature under N_2 atmosphere. After 48 h (TLC), excess pyridine was evaporated to half of its original volume. The solution was poured into an ice-cold saturated $NaHCO_3$ solution and the mixture was stirred for 30 min. The mixture was extracted with EtOAc (3×30 mL). The combined organic layers were dried over Na_2SO_4 and filtered. The filtrate was evaporated to dryness under reduced pressure. The crude material

thus obtained was purified over silica gel to furnish a white solid **34α** (2.5 g, 80%). Eluent: with EtOAc/petroleum ether (1:3); R_f (25% EtOAc/petroleum ether) 0.32; mp: 109–111 °C; $[\alpha]_D^{28}$ −18.6 (*c* 0.315, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 2.42 (s, 3H), 2.93 (d, 1H, *J*=4.68 Hz), 3.25–3.42 (m, 2H), 3.51 (s, 3H), 3.93 (m, 1H), 4.34–4.36 (m, 1H), 5.11 (d, 1H, *J*=3.05 Hz), 6.83 (d, 1H, *J*=2.9 Hz), 7.19–7.45 (m, 17H), and 7.78 (d, 2H, *J*=8.2 Hz); ^{13}C NMR (50 MHz, $CDCl_3$): δ 21.6, 56.1, 63.2 (CH_2), 63.4, 71.1, 86.8, 94.6, 127.0, 127.2, 128.2, 128.6, 129.8, 135.2, 136.6, 143.7, 144.4, and 144.5; HRMS (ES^+), *m*/*z* calcd for $(M+Na)^+$ $C_{33}H_{32}O_6SNa$: 579.1817. Found: 579.1813.

4.27. Methyl 2,3-dideoxy-3-*C*-*p*-toluenesulfonyl-6-*O*-trityl-β-D-*erythro*-hex-2-enopyranoside 34β

Compound **34β** (colorless jelly, 1.02 g, 61%) was synthesized from **33β** (1.2 g, 2.98 mmol) following the procedure described for the preparation of **34α**. R_f (33% EtOAc/petroleum ether) 0.36; $[\alpha]_D^{28}$ −119.8 (*c* 0.60, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 2.37 (s, 3H), 2.43–3.33 (m, 3H), 3.37 (s, 3H), 3.95–4.01 (m, 1H), 4.45–4.47 (m, 1H), 5.10 (br s, 1H), 6.84 (d, 1H, *J*=2 Hz), 7.19–7.41 (m, 17H), and 7.76 (d, 2H, *J*=8.3 Hz); ^{13}C NMR (50 MHz, $CDCl_3$): δ 21.5, 55.9, 61.6, 62.9 (CH_2), 76.4, 86.8, 95.4, 127.0, 127.7, 128.3, 128.5, 129.9, 135.4, 135.6, 142.5, 143.6, and 145.0. Anal. Calcd for $C_{33}H_{32}O_6S\cdot 1.5H_2O$: C, 67.91; H, 6.04. Found: C, 67.84; H, 5.91.

4.28. Methyl 2,3-dideoxy-6-*O*-trityl-2-*C*-(adenin-9-yl)-α-D-*gluco*pyranoside 36

To a well-stirred solution of adenine (0.44 g, 3.27 mmol) and TMG (0.3 mL, 2.35 mmol) in anhydrous DMF (20 mL) was added **34α** (0.26 g, 0.47 mmol) and the mixture was stirred at room temperature. After 3 days (TLC), the reaction mixture was diluted with EtOAc (40 mL) and filtered. The filtrate was washed with saturated $NaHCO_3$ solution. Organic layers were separated, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure. The crude material was purified over silica gel to obtain an inseparable mixture **35**. To a solution of **35** in anhydrous MeOH (20 mL) were added Na_2HPO_4 (0.6 g, 4.2 mmol) and (∼6%) Na–Hg (15 g). The resulting mixture was stirred at room temperature under N_2 atmosphere. After 4 h (TLC) the reaction mixture was diluted with EtOAc (50 mL) and filtered through a Celite bed. The filtrate was evaporated under reduced pressure. The residue was triturated with EtOAc (30 mL) and the organic layer was washed with saturated $NaHCO_3$ solution. The organic layers were separated, dried over Na_2SO_4, and filtered. The filtrate was concentrated under reduced pressure to obtain a residue. The residue was purified over silica gel to provide a hygroscopic solid **36** (0.11 g, 44% from **34α**). Eluent: $CHCl_3$/MeOH (49:1); $[\alpha]_D^{28}$ +29.9 (*c* 0.710, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 2.20–2.43 (m, 2H), 3.25 (s, 3H), 3.32–3.48 (m, 2H), 3.68–3.77 (m, 1H), 3.83–3.93 (m, 1H), 4.77 (d, 1H, *J*=3.1 Hz), 4.84–4.94 (m, 1H), 6.01 (br s, 2H), 7.11–7.36 (m, 9H), 7.45–7.49 (m, 6H), 7.98 (s, 1H), and 8.31 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 32.6 (CH_2), 51.4, 54.9 (CH_2), 64.7 (CH_2), 67.7, 70.5, 87.4, 96.4, 118.7, 127.2, 128.0, 128.5, 139.8, 143.5, 149.7, 152.8, and 155.3; HRMS (ES^+), *m*/*z* calcd for $(M+H)^+$ $C_{31}H_{32}N_5O_4$: 538.2454. Found: 538.2452.

4.29. Conversion of 36 to 29

To a solution of **36** (0.21 g, 0.39 mmol) in dry MeOH (20 mL) was added acetyl chloride (0.35 mL) at 0 °C and the solution was stirred for 4 h. To this solution was added dry pyridine (5 mL) and the resulting solution was evaporated under reduced pressure. Residual pyridine was co-evaporated with dry toluene (2×5 mL) and the residue was dissolved in dry DMF (5 mL). To this solution were added benzaldehyde dimethylacetal (0.65 mL, 4.48 mmol), *p*-TSA (36.1 mg, 0.19 mmol) and the resulting reaction mixture was heated at 100–110 °C under vacuum. After 2.5 h (TLC), the reaction mixture was cooled to room temperature and poured into an ice-cold, saturated $NaHCO_3$ solution. The aqueous layer was extracted with EtOAc (3×25 mL). Organic layers were pooled together, dried over anhydrous Na_2SO_4, filtered, and the filtrate was evaporated to dryness. The residue was purified over silica gel to obtain compound **29** (0.07 g, 39% in two steps).

4.30. Methyl 2,3-dideoxy-4,6-di-*O*-acetyl-2-*C*-(*N*-acetyladenin-9-yl)-α-D-*gluco*pyranoside 37

To a solution of **36** (0.11 g, 0.2 mmol) in anhydrous MeOH (10 mL) was added acetyl chloride (0.15 mL, 1.9 mmol) at 0 °C and the solution was stirred under N_2 atmosphere. After 4 h (TLC), anhydrous pyridine (2 mL) was added to this solution and the resulting solution was evaporated under reduced pressure. Residual pyridine was co-evaporated with toluene to obtain a residue. The residue was acetylated with acetyl chloride (0.7 mL, 9 mmol) in anhydrous pyridine (10 mL) in the presence of catalytic amount of DMAP (10 mg) in 20 h at ambient temperature. Usual work-up and purification over silica gel afforded **37** (0.76 g, 88%) as a hygroscopic solid. Eluent: EtOAc/petroleum ether (7:3); R_f (2% MeOH/DCM) 0.28; $[\alpha]_D^{27}$ +48.8 (*c* 0.676, $CHCl_3$); ^1H NMR (200 MHz, $CDCl_3$): δ 2.04 (s, 3H), 2.09 (s, 3H), 2.16–2.57 (m, 2H), 2.63 (s, 3H), 3.36 (s, 3H), 4.04–4.27 (m, 3H), 4.81 (d, 1H, *J*=3.0 Hz), 4.89–5.07 (m, 2H), 8.14 (s, 1H), 8.64 (s, 1H), and 8.82 (br s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 20.7, 20.8, 25.6, 30.0 (CH_2), 51.1, 55.3, 62.2 (CH_2), 66.2, 68.0, 77.2, 96.6, 121.1, 141.8, 149.1, 151.2, 152.3, 169.7, 170.5, 170.8; HRMS (ES^+), *m*/*z* calcd for $(M+H)^+$ $C_{18}H_{24}N_5O_7$: 422.1676. Found: 422.1681.

4.31. Methyl 2,3-dideoxy-6-*O*-trityl-2-*C*-(adenin-9-yl)-β-D-*gluco*pyranoside 39

Compound **39** (0.12 g, 43%) was obtained as a glassy solid from **34β** (0.3 g , 0.54 mmol) following the procedure described for the synthesis of compound **36**. $[\alpha]_D^{28}$ −101.9 (*c* 0.71, $CHCl_3$); IR (KBr): 1374, 1458, 1637, 1647, 1735, and 3448 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$): δ 2.35–2.43 (m, 1H), 2.56–2.72 (m, 1H), 3.35 (s, 3H), 3.39–3.57 (m, 2H), 3.72–3.86 (m, 2H), 4.13–4.41 (m, 1H), 5.05 (d, 1H, *J*=8.16 Hz), 5.85 (br s, 2H), 7.12–7.52 (m, 15H), 7.71 (s, 1H), 8.31 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$): δ 35.8 (CH_2), 56.0, 56.6, 64.9 (CH_2), 68.0, 77.1, 87.4, 101.6, 119.2, 127.3, 128.0, 128.6, 140.2, 143.4, 150.0, 152.6, 155.5; HRMS (ES^+), *m*/*z* calcd for $(M+H)^+$ $C_{31}H_{32}N_5O_4$: 538.2454. Found: 538.2451.

4.32. Methyl 2,3-dideoxy-4,6-di-*O*-acetyl-2-*C*-(*N*-acetyladenin-9-yl)-β-D-*gluco*pyranoside 40

Compound **40** (0.15 g, 88%) was obtained from **39** (0.22 g, 0.4 mmol) following the procedure described for the synthesis of compound **37**. Eluent: EtOAc/petroleum ether (7:3); R_f (2% MeOH/DCM) 0.39; colorless, hygroscopic solid; $[\alpha]_D^{27}$ −17. 2 (*c* 0.676, $CHCl_3$); IR (KBr): 1375, 1459, 1585, 1611, 1638, 1736, and 3430 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ 2.08 (s, 3H), 2.11 (s, 3H), 2.58–2.62 (m, 4H), 2.89–2.93 (m, 1H), 3.35 (s, 3H), 3.98–4.09 (m, 1H), 4.26–4.35 (m, 3H), 4.86–4.98 (m, 1H), 5.18 (d, 1H, *J*=8.0 Hz), 7.87 (s, 1H), 8.61 (br s, 1H), 8.65 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 20.8, 25.6, 32.1 (CH_2), 56.3, 56.9, 62.5 (CH_2), 66.3, 75.0, 101.0, 122.3, 143.2, 149.4, 151.9, 152.3, 169.8, 170.8. HRMS (ES^+), *m*/*z* calcd for $(M+H)^+$ $C_{18}H_{24}N_5O_7$: 422.1676. Found: 422.1670.

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Supplementary data

Crystallographic data (excluding structure factors) for the structures of compounds **4**, **5**, **8**, **9**, **17**, **23**, **24**, **29** have been deposited with the Cambridge Crystallographic Data Centre as supplementary publication nos. CCDC 687457–687464. Copies of the data can be obtained, free of charge, on application to CCDC, 12 Union Road, Cambridge CB2 1EZ, UK (fax: +44 (0)1223 336033 or e-mail: deposit@ccdc.cam.ac.uk). ^{1}H and ^{13}C NMR spectra of all new compounds are provided. Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.tet.2008.08.050.

References and notes

1. Pathak, T. *Chem. Rev.* **2002**, *102*, 1623–1667 and references cited therein.
2. Montgomery, J. A.; Clayton, S. D.; Thomas, H. J. *J. Org. Chem.* **1975**, *40*, 1923–1927.
3. (a) Ohrui, H.; Waga, T.; Meguro, H. *Biosci. Biotechnol. Biochem.* **1993**, *57*, 1040–1041; (b) Van Aerschot, A.; Meldgaard, M.; Schepers, G.; Volders, F.; Rozenski, J.; Busson, R.; Herdewijn, P. *Nucleic Acids Res.* **2001**, *29*, 4187–4194.
4. For selected publications on isonucleosides, see: (a) Wang, F.; Yang, Z.-J.; Jin, H.-W.; Zhang, L.-R.; Zhang, L.-H. *Tetrahedron: Asymmetry* **2007**, *18*, 2139–2146; (b) Nair, V.; Piotrowska, D. G.; Okello, M.; Vadakkan, J. *Nucleosides Nucleotides Nucleic Acids* **2007**, *26*, 687–690; (c) Chun, B.-K.; Wang, P.; Hassan, A.; Du, J.; Tharnish, P. M.; Murakami, E.; Stuyver, L.; Otto, M. J.; Schinazi, R. F.; Watanabe, K. A. *Nucleosides Nucleotides Nucleic Acids* **2007**, *26*, 83–97; (d) Yoshimura, Y.; Asami, K.; Matsui, H.; Tanaka, H.; Takahata, H. *Org. Lett.* **2006**, *8*, 6015–6018; (e) Jin, H.; Zheng, S.; Wang, Z.; Luo, C.; Shen, J.; Jiang, H.; Zhang, L.; Zhang, L. *J. Mol. Model.* **2006**, *12*, 781–791; (f) Alvarez de Cienfuegos, L.; Mota, A. J.; Robles, R. *Org. Lett.* **2005**, *7*, 2161–2164; (g) Chi, G.; Nair, V. *Nucleosides Nucleotides Nucleic Acids* **2005**, *24*, 1449–1468; (h) Mereyala, H. B.; Mamidyala, S. K. *Tetrahedron Lett.* **2004**, *45*, 2965–2966; (i) Nair, V.; Mickle, T.; Bera, S. *Nucleosides Nucleotides Nucleic Acids* **2003**, *22*, 239–247; (j) Aragones, S.; Bravo, F.; Diaz, Y.; Matheu, M. I.; Castillon, S. *Tetrahedron Lett.* **2003**, *44*, 3771–3773; (k) Chen, J.; Zhang, L. R.; Min, J. M.; Zhang, L. H. *Nucleic Acids Res.* **2002**, *30*, 3005–3014; (l) Wirsching, J.; Schulze, O.; Voss, J.; Giesler, A.; Kopf, J.; Adiwidjaja, G.; Balzarini, J.; De Clercq, E. *Nucleosides Nucleotides Nucleic Acids* **2002**, *21*, 257–274; (m) Nair, V. Antiviral Isonucleosides: Discovery, Chemistry and Chemical Biology. In *Recent Advances in Nucleosides*; Chu, C. K., Ed.; Elsevier Science B.V.: Amsterdam, 2002; pp 149–166; (n) Bera, S.; Nair, V. *Tetrahedron Lett.* **2001**, *42*, 5813–5815; (o) Bravo, F.; Diaz, Y.; Castillon, S. *Tetrahedron: Asymmetry* **2001**, *12*, 1635–1643; (p) Chun, B. K.; Song, G. Y.; Chu, C. K. *J. Org. Chem.* **2001**, *66*, 4852–4858; (q) Lei, Z.; Min, J. M.; Zhang, L. H. *Tetrahedron: Asymmetry* **2000**, *11*, 2899–2906; (r) Yamada, K.; Sakata, S.; Yoshimura, Y. *J. Org. Chem.* **1998**, *63*, 6891–6899.
5. (a) Lizcano, J. M.; Goeransson, O.; Toth, R.; Deak, M.; Morrice, N. A.; Boudeau, J.; Hawley, S. A.; Udd, L.; Maekelae, T. P.; Hardie, D. G.; Alessi, D. R. *EMBO J.* **2004**, *23*, 833–843; (b) Wu, Q.; Wan, J.; Xia, Y.; Zhou, J.; Qu, F.; Peng, L. *Heterocycles* **2004**, *63*, 671–679; (c) Wolan, D. W.; Cheong, C.-G.; Greasley, S. E.; Wilson, I. A. *Biochemistry* **2004**, *43*, 1171–1183; (d) Kocabalkanli, A.; Schinazi, R. F. *Farmaco* **2002**, *57*, 993–997; (e) Yokota, S. *Pediatr. Int.* **2002**, *44*, 196–198; (f) Musi, N.; Goodyear, L. J. *Current Drug Targets: Immune, Endocr. Metabol. Disord.* **2002**, *2*, 119–127; (g) Nair, V.; Sosnouski, D. S.; Zhu, Q. *Nucleosides Nucleotides Nucleic Acids* **2001**, *20*, 735–738; (h) Moya, J.; Pizarro, H.; Jashes, M.; De Clercq, E.; Sandino, A. M. *Antiviral Res.* **2000**, *48*, 125–130; (i) Shuto, S.; Haramuishi, K.; Fukuoka, M.; Matsuda, A. *J. Chem. Soc., Perkin Trans. 1* **2000**, 3603–3609; (j) Minakawa, N.; Matsuda, A. *Curr. Med. Chem.* **1999**, *6*, 615–628; (k) Hatse, S.; De Clercq, E.; Balzarini, J. *Biochem. Pharmacol.* **1999**, *58*, 539–555; (l) Wilson, D. V.; Beddows, C. G. *Experientia* **1974**, *30*, 588–590; (m) Wilson, D. V.; Beddows, C. G. *Experientia* **1974**, *30*, 226–228; (n) Beddows, C. G.; Wilson, D. V. *J. Chem. Soc., Perkin Trans. 1* **1973**, *20*, 2345–2348.
6. (a) Leban, I.; Jeselnik, M.; Sieler, J.; Kobe, J. *Nucleosides Nucleotides Nucleic Acids* **2004**, *23*, 521–530; (b) Van Aerschot, A.; Schepers, G.; Busson, R.; Rozenski, J.; Neyts, J.; De Clercq, E.; Herdewijn, P. *Antiviral Chem. Chemother.* **2003**, *14*, 23–30; (c) Gu, P.; Morral, J.; Wang, J.; Rozenski, J.; Busson, R.; Van Aerschot, A.; De Clercq, E.; Herdewijn, P. *Antiviral Chem. Chemother.* **2003**, *14*, 31–37; (d) Li, Z.; Chen, S.; Jiang, N.; Cui, G. *Nucleosides Nucleotides Nucleic Acids* **2003**, *22*, 419–435; (e) Koumbis, A. E.; Gallos, J. K. *Curr. Org. Chem.* **2003**, *7*, 771–797; (f) Van Aerschot, A.; Schepers, G.; Busson, R.; Neyts, J.; De Clercq, E.; Herdewijn, P. *Nucleosides Nucleotides Nucleic Acids* **2003**, *22*, 849–851; (g) Al-Masoud, N. A.; Al-Soud, Y. A. *Nucleosides Nucleotides Nucleic Acids* **2002**, *21*, 361–375; (h) Cameron, C. E.; Castro, C. *Curr. Opin. Infect. Dis.* **2001**, *14*, 757–764; (i) Klewer, D. A.; Zhang, P.; Bergstrom, D. E.; Davisson, V. J.; LiWang, A. *Biochemistry* **2001**, *40*, 1518–1527; (j) Ramasamy, K. S.; Tam, R. C.; Bard, J.; Averett, D. R. *J. Med. Chem.* **2000**, *43*, 1019–1028; (k) Liu, M.-C.; Luo, M.-Z.; Mozdziesz, D. E.; Lin, T.-S.; Dutschman, G. E.; Gullen, E. A.; Cheng, Y.-C.; Sartorelli, A. C. *Nucleosides Nucleotides Nucleic Acids* **2000**, *19*, 603–618.
7. (a) Sakakibara, T.; Sudoh, R. *Carbohydr. Res.* **1976**, *50*, 191–196; (b) Rajabalee, F. J.-M. *Carbohydr. Res.* **1973**, *26*, 219–224; (c) Nakagawa, T.; Sakakibara, T.; Kumazawa, S. *Tetrahedron Lett.* **1970**, 1645–1648.
8. (a) Prevost, N.; Rouessac, F. *Tetrahedron Lett.* **1997**, *38*, 4215–4218; (b) Prevost, N.; Rouessac, F. *Synth. Commun.* **1997**, *27*, 2325–2335; (c) The additional problems of using carbohydrate enones as precursors have been discussed in detail, see: Ravindran, B.; Deshpande, S. G.; Pathak, T. *Tetrahedron* **2001**, *57*, 1093–1098.
9. For reviews, see: (a) Sanki, A.; Pathak, T. *Proc. Indian Natn. Sci. Acad.* **2005**, *71A*, 245–266; (b) Pathak, T. *Tetrahedron* **2008**, *64*, 3605–3628; (c) Pathak, T.; Bhattacharya, R. *Carbohydr. Res.* **2008**, *343*, 1980–1998.
10. (a) Sanki, A. K.; Pathak, T. *Synlett* **2002**, 1241–1244; (b) Sanki, A. K.; Pathak, T. *Tetrahedron* **2003**, *59*, 7203–7214.
11. For the addition of amines to **1α**/**1β**, see: (a) Ravindran, B.; Sakthivel, K.; Suresh, C. G.; Pathak, T. *J. Org. Chem.* **2000**, *65*, 2637–2641; (b) Suresh, C. G.; Ravindran, B.; Pathak, T.; Narasimha Rao, K.; Sasidhar Prasad, J. S.; Lokanath, N. K. *Carbohydr. Res.* **2002**, *337*, 1507–1512.
12. For the addition of amines to **2α**/**2β**, see: Das, I.; Pathak, T. *Org. Lett.* **2006**, *8*, 1303–1306.
13. For the addition of carbon nucleophiles to **1α**/**1β** and **2α**/**2β**, see: Sanki, A. K.; Suresh, C. G.; Falgune, U. D.; Pathak, T. *Org. Lett.* **2003**, *5*, 1285–1288.
14. Structural elucidation on the basis of NMR alone may lead to erroneous conclusions. For the problems associated with structural determination of related products, see: Sakakibara, T.; Suzuki, K.; Sakai, A.; Shindo, M.; Nagano, C.; Narumi, S.; Kajihara, Y.; Mochizuki, K. *Tetrahedron Lett.* **2003**, *44*, 5711–5714.
15. (a) Sakakibara, T.; Tokuda, K.; Hayakawa, T.; Seta, A. *Carbohydr. Res.* **2000**, *327*, 489–496; (b) Sakakibara, T.; Takaide, A.; Sata, A. *Carbohydr. Res.* **1992**, *226*, 271–278; (c) Sakakibara, T.; Nakagawa, T. *Carbohydr. Res.* **1987**, *163*, 239–246; (d) Baer, H. H.; Hanna, Z. S. *Carbohydr. Res.* **1980**, *85*, 136–142; (e) Sakakibara, T.; Seta, A.; Tachimori, Y.; Takamoto, T.; Sudoh, R. *Chem. Lett.* **1977**, 1365–1366; (f) Sakakibara, T.; Sudoh, R. *J. Chem. Soc., Chem. Commun.* **1974**, 69–70; (g) Paulsen, H.; Greve, W. *Chem. Ber.* **1974**, *107*, 3013–3019; (h) Baer, H. H.; Ong, K. S. *Can. J. Chem.* **1968**, *46*, 2511–2517.
16. (a) Sakakibara, T.; Ohkita, N.; Nakagawa, T. *Bull. Chem. Soc. Jpn.* **1992**, *65*, 446–451; (b) Sakakibara, T.; Tachimori, Y.; Sudoh, R. *Tetrahedron* **1984**, *40*, 1533–1539; (c) Sakakibara, T.; Sudoh, R. *J. Org. Chem.* **1977**, *42*, 1746–1750; (d) Sakakibara, T.; Sudoh, R.; Nakagawa, T. *J. Org. Chem.* **1973**, *38*, 2179–2184; (e) Bishop, E. O.; Guthrie, R. D.; Lewis, J. E. *Carbohydr. Res.* **1967**, *5*, 477–478; (f) Coxon, B. *Tetrahedron* **1965**, *21*, 3481–3503.
17. Conway, E.; Guthrie, R. D.; Gero, S. D.; Lukas, G.; Sepulchre, A. *J. Chem. Soc., Perkin Trans. 2* **1974**, 542–546.
18. Truce, W. E.; Levy, A. J. *J. Am. Chem. Soc.* **1961**, *83*, 4641–4643.
19. (a) Kawana, M.; Kuzuhara, H.; Emoto, S. *Bull. Chem. Soc. Jpn.* **1981**, *54*, 1492–1504; (b) Su, T.-L.; Klein, R. S.; Fox, J. J. *J. Org. Chem.* **1981**, *46*, 1790–1792; (c) Bock, K.; Pedersen, C.; Thiem, J. *Carbohydr. Res.* **1979**, *73*, 85–91; (d) Montgomery, J. N.; Thorpe, M. C.; Clayton, S. D.; Thomas, H. J. *Carbohydr. Res.* **1974**, *32*, 404–407; (e) Casini, G.; Goodman, L. *J. Am. Chem. Soc.* **1964**, *86*, 1427–1431.
20. (a) Kawana, M.; Koresawa, T.; Kuzuhara, H. *Bull. Chem. Soc. Jpn.* **1983**, *56*, 1095–1100; (b) Liptak, A.; Neszmelyi, A.; Kovac, P.; Hirsch, J. *Tetrahedron* **1981**, *37*, 2379–2382; (c) Yamashita, A.; Rosowsky, A. *J. Org. Chem.* **1976**, *41*, 3422–3425.
21. (a) Wu, J. C.; Pathak, T.; Tong, W.; Vial, J. M.; Remaud, G.; Chattopadhyaya, J. *Tetrahedron* **1988**, *44*, 6705–6722; (b) Bera, S.; Langley, G. J.; Pathak, T. *J. Org. Chem.* **1998**, *63*, 1754–1760.
22. Weber, J. F.; Talhouk, J. W.; Nachman, R. J.; You, T.-P.; Halaska, R. C.; Williams, T. M.; Mosher, H. S. *J. Org. Chem.* **1986**, *51*, 2702–2706.
23. Williams, N. R. *Adv. Carbohydr. Chem.* **1970**, *25*, 109–179.
24. Truce, W. E.; Levy, A. J. *J. Org. Chem.* **1963**, *28*, 679–682.
25. Desulfonylated nucleosides were isolated as peracetylated derivatives **25**, **26**, **37**, and **40** for their easy isolation and characterization. For further modifications these compounds may be deacetylated and reprotected. Alternatively, compounds **5** and **9**, immediately after desulfonylation and debenzyledination (Scheme 7) may be protected with other masking groups and isolated. For adenine analogues, the tritylated compounds **39** (Scheme 10) and **36** (Scheme 11) may be functionalized directly depending on the requirement.