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2-Substituted 6-(Het)aryl-7-deazapurine Ribonucleosides: Synthesis, Inhibition of Adenosine Kinases, and Antimycobacterial Activity

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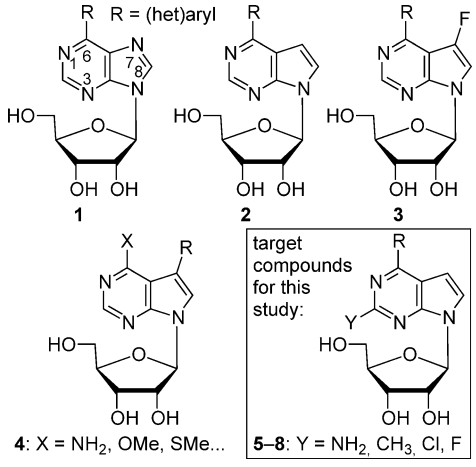
A series of 6-(hetero)aryl- or 6-methyl-7-deazapurine ribonucleosides bearing a substituent at position 2 (Cl, F, NH_2, or CH_3) were prepared by cross-coupling reactions at position 6 and functional group transformations at position 2. Cytostatic, antiviral, and antimicrobial activity assays were performed. The title compounds were observed to be potent and selective inhibitors of *Mycobacterium tuberculosis* adenosine kinase (ADK), but not human ADK; moreover, they were found to be non-cytotoxic. The antimycobacterial activities against *M. tuberculosis*, however, were only moderate. The reason for this could be due to either poor uptake through the cell wall or to parallel biosynthesis of adenosine monophosphate by the salvage pathway.

Introduction

Our recent systematic study of substituted purine and 7-deazapurine (IUPAC name: pyrrolo[2,3-*d*]pyrimidine, but purine numbering is used herein for clarity) ribonucleosides has revealed several important classes of potent nucleoside cytostatics. 6-(Hetero)arylpurine ribonucleosides **1** displayed sub-micromolar cytostatic activities and anti-HCV effects.[1,2] 6-(Het)aryl-7-deazapurine ribonucleosides bearing H or F at position 7 (**2** and **3**),[3] as well as 7-(het)aryl-7-deazapurine nucleosides **4**[4,5] displayed nanomolar cytostatic effects, and selected compounds are now under preclinical evaluation. Most sugar-modified derivatives[6] and even monophosphate prodrugs[7] derived from nucleosides **2**–**4** were found to be less active or inactive. Both types of modified 7-deazapurine nucleosides were observed to be inhibitors of adenosine kinases.[8,9] The 6-(het)aryl-7-deazapurine nucleosides **2** and **3** were found[8] to be potent and selective inhibitors of *Mycobacterium tuberculosis* (Mtb) adenosine kinase (ADK) and did not inhibit human ADK. Derivatives bearing bulkier (het)aryl groups were even non-cytotoxic, but the observed antimycobacterial activities were only moderate.[8] Some 7-heteroaryl-7-deazaadenosine derivatives inhibited both human and Mtb ADK, whereas those with bulkier aryl groups were again selective inhibitors of the Mtb enzyme.[9] Because some other studies were also reported on antimycobacterial agents based on purine and deazapurine nucleosides,[10,11] and to further validate Mtb ADK as a target for antimycobacterial therapy,[12] we decided to further explore the 6-(het)aryl-7-deazapurine nucleosides and modify the skeleton by adding a small substituent (halogen, methyl, or amino group) to position 2 (similar substitution on purine nucleosides led[11] to more selective Mtb ADK inhibitors). As 6-methylpurine[13] and -7-deazapurine[5,14] nucleosides are also interesting biologically active compounds, we extended the series to 2-substituted 6-methyl-7-deazapurine ribonucleosides as well.



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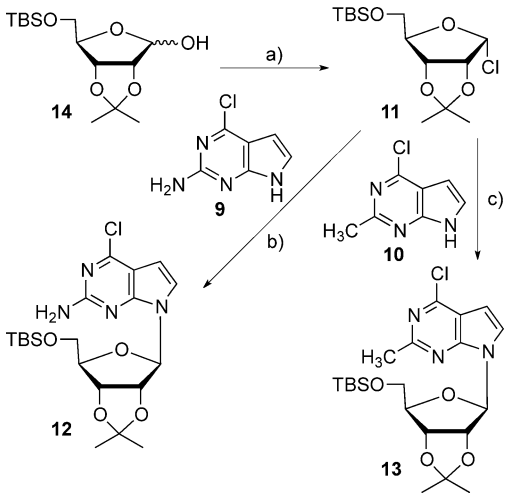
Results and Discussion

Chemistry

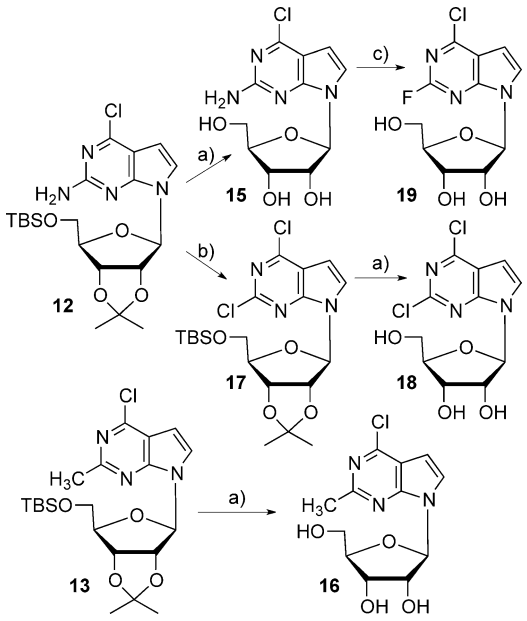
Synthesis of the target 2,6-disubstituted 7-deazapurine ribonucleosides **5**–**8** relied on palladium-catalyzed cross-coupling of either protected or unprotected 2-substituted 6-chloro-7-deazapurine ribonucleosides. The corresponding intermediates were prepared by glycosylation and nucleoside transformation chemistry. Potassium salts[15] of commercial 2-amino- (**9**) and known[5,16] 2-methyl-6-chloro-7-deazapurine (**10**) bases were glycosylated with 5′-*O*-TBS-2,3-*O*-isopropylidene-protected halosugar **11**[17] to afford protected ribonucleosides **12** and **13**. The halosugar **11** was formed as we previously described, from lactol **14** by Appel's chlorination in toluene,[5] and quickly used in the displacement reaction (Scheme 1).



Scheme 1. *Reagents and conditions*: a) CCl_4, $P(NMe_2)_3$, toluene, −30 °C, 5 min; b) KOH, TDA-1, MeCN, rt, 24 h; c) KOH, TDA-1, toluene, rt, 24 h.

Glycosylation of 2-methyl-7-deazapurine **10** was performed in toluene[3,10b] to give the desired 2-methylribonucleoside **13** as a single β-anomer in good (64%) yield. Because of the low solubility of 2-amino-6-chloro-7-deazapurine **9** in toluene, glycosylation of this compound was performed in acetonitrile[15] to obtain the known ribonucleoside **12**[18] in 42% yield.

Deprotection of TBS-isopropylidene nucleosides **12** and **13** was achieved by treatment with 90% trifluoroacetic acid (TFA) to afford free nucleosides **15** and **16** in high yields. A non-aqueous diazotization/chloro-dediazoniation reaction[19] of protected 2-amino-7-deazapurine nucleoside **12** in the presence of acetyl chloride and $BnEt_3N^+NO_2^-$ afforded the protected 2,6-dichlororibonucleoside **17** in good yield (67%, Scheme 2). It was also deprotected by treatment with TFA to give free nucleoside **18**. The last intermediate was prepared by diazotization/fluoro-dediazoniation of unprotected nucleoside **15** in the presence of HF·pyridine and *tert*-butyl nitrite[20] to give the desired 2-fluoro-6-chlorodeazapurine derivative **19** in good yield (62%).

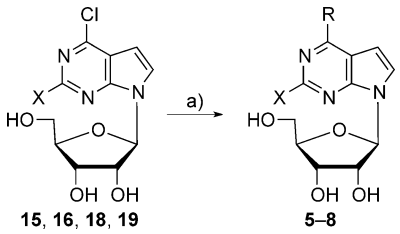


Scheme 2. *Reagents and conditions*: a) 90% aq. TFA, rt, 30 min; b) AcCl, $BnEt_3N^+NO_2^-$, CH_2Cl_2, 0 °C, 20 min, (67%); c) 70% HF·Py, *tert*-BuONO, −20 °C, 30 min, (62%).

The unprotected 2-substituted 6-chloro-7-deazapurine ribonucleosides **15**, **16**, **18**, and **19** were used as intermediates for (hetero)arylation at position 6 by aqueous-phase Suzuki–Miyaura cross-couplings[21] with diverse (hetero)arylboronic acids. The aryl groups included 2- and 3-furyl and -thienyl as examples of the most active cytostatics from previous work,[3] and bulkier phenyl, benzofuryl, and dibenzofuryl groups that did not show any cytotoxicity in a previous study.[8] The coupling reactions were performed in the presence of $Pd(OAc)_2$, TPPTS ligand, and sodium carbonate in a water/acetonitrile 2:1 mixture at 100 °C (Scheme 3).

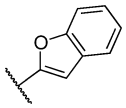
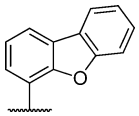
In this way, 28 title 2-substituted-6-(het)aryl-7-deazapurine ribonucleosides **5a**–**g** to **8a**–**g** were obtained in moderate to good yields (Table 1). As previously described for 2,6-dichloropurines[22] and 2,6-dichloro-7-deazapurines,[23] regioselectivity of Suzuki–Miyaura cross-coupling in the case of 2,6-dichlororibonucleoside **18** was achieved by the use of a limited amount of boronic acid (1.1 equiv) and lower catalyst loading.

To complete the series of compounds, we decided to prepare 2-substituted 6-methyl-7-deazapurine ribonucleosides **5h**–**8h** (Scheme 4). As we knew from our previous unpublished work on 7-deazapurine nucleosides that methylation at position 6 by Suzuki–Miyaura cross-coupling with methylboronic acid is inefficient, we used cross-coupling reactions with highly reactive trimethylaluminum[24] using protected nucleosides (Scheme 4). Although previously published examples[24] have shown that direct methylation of free 2-amino-6-chloropurines is possible by using a greater excess of trimethylaluminum, we preferred to use a cleaner method with temporary protection of the amino function by an orthogonal trifluoroacetamide group (Scheme 4). Nucleoside **12** was therefore trifluoroacetylated at the amino group to afford intermediate **20**, which was transformed into its 6-methyl derivative **21** upon reaction with

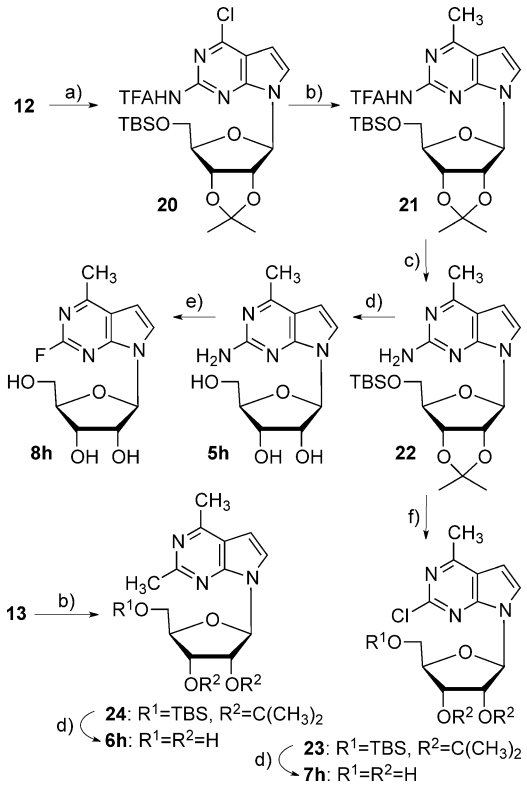


Scheme 3. *Reagents and conditions*: a) R-B(OH)$_2$, Pd(OAc)$_2$, TPPTS, Na_2CO_3, H_2O/MeCN (2:1), 100 °C.

Table 1. Products and yields of cross-coupling products (see Scheme 3).

	R	Product: Yield [%] 5, X = NH_2	6, X = CH_3	7, X = Cl	8, X = F
a		**5a**: 63	**6a**: 79	**7a**: 82	**8a**: 93
b		**5b**: 67	**6b**: 97	**7b**: 56	**8b**: 98
c		**5c**: 50	**6c**: 98	**7c**: 78	**8c**: 92
d		**5d**: 64	**6d**: 91	**7d**: 58	**8d**: 80
e		**5e**: 81	**6e**: 74	**7e**: 40	**8e**: 84
f		**5f**: 74	**6f**: 79	**7f**: 88	**8f**: 97
g		**5g**: 85	**6g**: 66	**7g**: 64	**8g**: 67

trimethylaluminum under palladium catalysis in good yield (69%). After deprotection of the amino group under basic conditions, diazotization/chloro-dediazoniation (as described above) gave protected 2-chloro-6-methylribonucleoside **23** in moderate yield (45%). Final deprotection of 2-amino and 2-chloro compounds **22** and **23** under acidic conditions afforded 6-methylribonucleosides **5h** and **7h**. Diazotization/fluoro-dediazoniation of compound **5h** furnished 2-fluoro-6-methyl-7-deazapurine nucleoside **8h**. Palladium-catalyzed methylation of protected nucleoside **13** followed by deprotection of intermediate **24** afforded the 2,6-dimethyldeazapurine nucleoside **6h**.



Scheme 4. *Reagents and conditions*: a) TFA_2O, DIPEA, CH_2Cl_2, rt, 2 h; b) $AlMe_3$, $Pd(PPh_3)_4$, THF, 75 °C, 90 min; c) MeONa, MeOH, rt, 2 h; d) 90% aq. TFA, rt, 30 min; e) 70% HF·Py, *tert*-BuONO, −20 °C, 30 min; f) AcCl, $BnEt_3N^+NO_2^-$, CH_2Cl_2, 0 °C, 20 min.

Biological activity

The in vitro cytotoxic/cytostatic activities of title nucleosides **5a**–**h** to **8a**–**h** were initially evaluated against six cell lines derived from human solid tumors, including lung (A549 cells) and colon (HCT116 and HCT116p53$^{-/-}$) carcinomas, as well as leukemia cell lines (CCRF-CEM, CEM-DNR, K562, and K562-TAX); for comparison, non-malignant BJ and MRC-5 fibroblasts were also assayed. Concentrations that inhibit cell growth by 50% (IC_{50} values) were determined by quantitative metabolic staining with 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT)[25] following a three-day treatment (Table 2). Most compounds showed no cytotoxicity, except for 6-benzofuryl- (**7f**, **8f**) and 6-dibenzofuryl- (**5g**, **7g**) deazapurine derivatives, and 2-fluoro-7-deazapurine nucleosides **8a** and **8b**, which exerted micromolar effects. This confirms that the introduction of a substituent at position 2 is not permitted in this class of cytostatic nucleosides.

Compounds were also tested in Huh-7 cells harboring subgenomic reporter replicons derived from HCV subtypes 1B and 2A, as well as activity against RSV and HRV-C viruses. Partial inhibition of the replicon reporter or virus replication was observed only with compounds **5g**, **7f**, **7g**, **8a**,**b**,**f**, which showed cytotoxicity as well (Table 3). The correlation of antiviral effects with cytotoxicity suggests that the activity detected is a reflection of interference with host target(s).

All title nucleosides **5a**–**h** to **8a**–**h** were tested for the inhibition of human and Mtb ADKs (see ref. [7a] for cloning expression and purification of these enzymes). None of the tested compounds showed any significant inhibition of human ADK, whereas most of them were potent and selective inhibitors of the Mtb enzyme (Table 4). While the 2-amino- and 2-methyl-7-deazapurine derivatives **5** and **6** were found to be rather weak inhibitors of Mtb ADK, most of the 2-chloro and 2-fluoro deriv-

Table 2. Cytotoxic/cytostatic activities of selected compounds.[a]

Compd	CC_{50} [μM]		IC_{50} [μM]						
	BJ	MRC-5	CCRF-CEM	CEM-DNR	K562	K562-TAX	A549	HCT116	HCT116p53$^{-/-}$
5g	75.22±14.11	130.2±17.2	26.5±0.6	35.1±1.7	12.4±2.8	29.6±2.1	39.7±3.1	10.9±1.1	26.5±1.9
7f	101.2±5.9	108.6±10.2	5.80±1.10	9.96±1.10	11.0±0.7	27.1±1.6	26.5±3.4	9.54±2.15	13.8±1.9
7g	30.71±1.87	130.6±19.2	49.8±0.5	30.9±4.7	>50	36.0±1.2	24.2±3.8	12.7±2.8	22.6±6.4
8a	30.59±4.47	135.8±11.3	2.22±0.33	47.2±4.5	6.18±0.94	23.1±5.8	29.4±14.0	7.79±2.41	18.8±7.1
8b	136.0±21.8	>150	38.4±5.3	>50	49.2±1.3	>50	>50	>50	>50
8f	>150	>150	38.1±3.4	37.7±2.1	47.6±0.6	33.8±1.9	>50	48.5±2.4	>50

[a] Values are the mean±SD of three independent experiments; compounds not listed here were inactive: CC_{50}>150 μM.

Table 3. Antiviral activities of selected compounds.[a]

Compd	MT4		HCV 1B replicon		HCV 2A replicon		RSV		HRV-C	
	EC_{50} [μM]	CC_{50} [μM]	EC_{50} [μM]	CC_{50} [μM]	EC_{50} [μM]	CC_{50} [μM]	EC_{50} [μM]	CC_{50} [μM]	EC_{50} [μM]	CC_{50} [μM]
5g	>50	11.3	7.28	42.2	13.2	18.4	>50	34.8	>50	>50
7f	>50	7.89	3.98	26.6	3.27	5.90	>50	3.46	>50	>50
7g	>50	>50	>40	>40	30.2	12.6	20.9	>50	>50	>50
8a	>50	7.75	6.73	>40	15.3	>40	3.67	6.49	>50	>50
8b	>50	47.3	32.0	>40	>40	>40	13.7	46.0	>50	>50
8f	>50	47.4	17.8	>40	35.4	>40	>50	23.6	>50	>50

[a] Data show the results of a single experiment; compounds not listed here were inactive (EC_{50}>50 μM, CC_{50}>40 μM).

atives exerted sub-micromolar or even nanomolar IC_{50} values with low cytotoxicity. The 2-fluoro-6-benzofuryl-7-deazapurine nucleoside **8f** was the most potent and selective compound, with IC_{50}=1.2 nM. Finally, all compounds were tested for activity against *M. tuberculosis* (strain My 331/88). Unfortunately, most compounds were entirely inactive, and only a few benzofuryl or dibenzofuryl nucleosides **6g**, **7f**, **8f**, **8g** showed moderate effects, with MIC values of 32 or 62.5 μM. Similar to previous reports,[8,9] it seems that even highly potent Mtb ADK inhibitors do not show significant antimycobacterial activities. The reason could be either in poor penetration through the cell wall or parallel biosynthesis of adenosine monophosphate (AMP) by a salvage pathway. In principle, the issue of poor uptake could be solved by the design of suitable lipophilic prodrugs. However, in our previous studies[6,7] we tested several types of nucleotide prodrugs, and all were even less active than the parent nucleosides, showing that penetration of the mycobacterial cell wall by nucleotide prodrugs is apparently much more complicated than for eukaryotic cells, and this would require a dedicated systematic study.

Conclusions

We developed a facile synthesis of a series of 6-(het)aryl-7-deazapurine ribonucleosides bearing an amino, methyl, chloro, or fluoro group at position 2 based on aqueous Suzuki cross-coupling at position 6 combined with other functional group transformations at position 2. The title compounds did not exert any significant cytotoxicity, but many of them (in particular 2-chloro and 2-fluoro derivatives) were very potent and selective inhibitors of Mtb—but not human—ADK. Unfortunately, they did not show antimycobacterial activity which is likely due to limited uptake through the Mtb cell wall and/or

Table 4. Inhibition of human and Mtb ADK and antimycobacterial activities.

Compd	ADK IC_{50} [μM][a]		Mtb MIC [μM][b]
	human	Mtb	
5a	>20	4.00±0.22	>250
5b	>20	1.15±0.08	>250
5c	>10	6.00±0.42	>250
5d	>10	3.00±0.25	>250
5e	>10	3.7±0.22	>250
5f	>5	0.30±0.02	250
5g	>10	>10	>250
5h	>10	>10	>250
6a	>20	>10	>250
6b	>20	1.80±0.16	>250
6c	>10	>10	>250
6d	>10	4.5±0.44	>250
6e	>20	0.50±0.05	>250
6f	>20	0.36±0.03	>250
6g	>20	>10	62.5
6h	>20	>5	>250
7a	>10	0.2±0.02	250
7b	>10	0.14±0.02	125
7c	>5	0.14±0.01	>250
7d	>5	0.12±0.01	125
7e	>20	0.18±0.01	250
7f	>5	0.1±0.01	62.5
7g	>5	>5	>250
7h	>10	>5	>250
8a	>10	0.11±0.01	>250
8b	>20	0.090±0.003	250
8c	>10	0.080±0.005	>250
8d	>10	0.050±0.004	125
8e	>10	0.060±0.005	250
8f	>10	0.0012±0.0001	62.5
8g	>20	0.18±0.02	32
8h	>10	>10	250

[a] Values are the mean±SD of three independent experiments. [b] Results of a single experiment.

parallel biosynthesis of AMP by a salvage pathway. In our future work, we plan to study new types of prodrugs, as well as to target other enzymes of Mtb metabolism.

Experimental Section

Chemistry

NMR spectra were acquired in DMSO on Bruker AVANCE 600 (^{1}H at 600.1 MHz and ^{13}C at 150.9 MHz), Bruker AVANCE 500 (^{1}H at 500.0 MHz, ^{13}C at 125.7 MHz, and ^{19}F at 470.3 MHz), and/or Bruker AVANCE 400 (^{1}H at 400.0 MHz, ^{13}C at 100.6 MHz, and ^{19}F at 315.5 MHz) NMR spectrometers. Chemical shifts (δ scale, in ppm) were referenced to the residual solvent signal (2.50 ppm for ^{1}H and 39.7 ppm for ^{13}C). ^{19}F NMR spectra were referenced to C_6F_6 (−163.0 ppm) as an external standard. Coupling constants (J) are given in Hz. The complete assignment of ^{1}H and ^{13}C signals was performed by an analysis of the correlated homonuclear H,H-COSY and heteronuclear H,C-HSQC and H,C-HMBC spectra.

2-Methyl-4-chloro-7*H*-pyrrolo[2,3-*d*]pyrimidine (10). Compound **10** was prepared as described previously.[5,16] Analytical data for compound **10** are in agreement with published data.[5,16]

2-Amino-4-chloro-7-(2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (12). Halosugar **11** was prepared from 2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-D-ribofuranose **14**[17] (13.53 g, 44.5 mmol) in toluene (100 mL) at −30 °C, as previously described.[5] Compound **11** was then dissolved in MeCN (100 mL) and added to a vigorously stirred suspension of commercially available 2-amino-4-chloro-7*H*-pyrrolo[2,3-*d*]pyrimidine **9** (5 g, 29.7 mmol), powdered KOH (3.33 g, 59.3 mmol), and TDA-1 (4.74 mL, 14.8 mmol) in MeCN (100 mL). The mixture was stirred for 24 h and then aqueous NH_4Cl (sat, 200 mL) was added, and the mixture extracted with $CHCl_3$ (400 mL, then 2×100 mL). The combined organic extracts were dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica (hexanes/EtOAc, 10:1) to afford **12** (5.65 g, 42%) as a light-yellow oil. Analytical data for compound **12** are in agreement with published data.[18]

2-Methyl-4-chloro-7-(2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (13). The dried organic extract from the preparation of halosugar **11** was added directly to a vigorously stirred suspension of 2-methyl-4-chloro-7*H*-pyrrolo[2,3-*d*]pyrimidine **10** (2 g, 11.9 mmol), powdered KOH (1.34 g, 23.8 mmol), and TDA-1 (1.91 mL, 5.95 mmol) in toluene (40 mL). The mixture was stirred for 24 h and then aqueous NH_4Cl (sat, 100 mL) was added. The toluene organic extract was dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica (hexanes/EtOAc, 20:1) to afford **13** (3.47 g, 64%) as a colorless oil: ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): δ = −0.05 and −0.04 (2 s, 2×3 H, CH_3Si), 0.81 (s, 9 H, $(CH_3)_3C$), 1.33 and 1.54 (2 s, 2×3 H, $(CH_3)_2C$), 2.65 (s, 3 H, CH_3-2), 3.69 (dd, 1 H, J_{gem} = 11.2 Hz, $J_{5'a,4'}$ = 5.5 Hz, H-5′a), 3.74 (dd, 1 H, J_{gem} = 11.2 Hz, $J_{5'b,4'}$ = 4.9 Hz, H-5′b), 4.16 (td, 1 H, $J_{4',5'a} = J_{4',5'b}$ = 5.2 Hz, $J_{4',3'}$ = 3.4 Hz, H-4′), 4.95 (dd, 1 H, $J_{3',2'}$ = 6.3 Hz, $J_{3',4'}$ = 3.4 Hz, H-3′), 5.26 (dd, 1 H, $J_{2',3'}$ = 6.3 Hz, $J_{2',1'}$ = 2.7 Hz, H-2′), 6.32 (d, 1 H, $J_{1',2'}$ = 2.7 Hz, H-1′), 6.67 (d, 1 H, $J_{5,6}$ = 3.8 Hz, H-5), 7.78 ppm (d, 1 H, $J_{6,5}$ = 3.8 Hz, H-6); MS (ESI) m/z (%): 454 (50) $[M+H]^+$, 476 (100) $[M+Na]^+$; HRMS (ESI) for $C_{21}H_{33}O_4N_3ClSi$ $[M+H]^+$ calcd: 454.19234, found: 454.19231.

2,4-Dichloro-7-(2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (17). Compound **17** was prepared according to a previously described method.[19] A solution of BTEA-NO_2 (1.63 g, 6.84 mmol) in dry CH_2Cl_2 (15 mL) was added dropwise to a stirred, argon-purged solution of AcCl (0.61 mL, 8.55 mmol) in dry CH_2Cl_2 (25 mL) at 0 °C. Then, a solution of compound **12** (780 mg, 1.71 mmol) in dry CH_2Cl_2 (5 mL) was added dropwise to the mixture at 0 °C. After 15–20 min of stirring at room temperature, aqueous $NaHCO_3$ (sat, 50 mL) was added and the mixture extracted with $CHCl_3$ (50 mL, then 2×20 mL). The combined organic extracts were dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica (hexanes/EtOAc, 20:1) to afford **17** (547 mg, 67%) as a colorless oil: ^{1}H NMR (400 MHz, [D$_6$]DMSO): δ = −0.03 (s, 6 H, CH_3Si), 0.81 (s, 9 H, $(CH_3)_3C$), 1.33 and 1.55 (2 s, 2×3 H, $(CH_3)_2C$), 3.69 (dd, 1 H, J_{gem} = 11.2 Hz, $J_{5'a,4'}$ = 5.5 Hz, H-5′a), 3.76 (dd, 1 H, J_{gem} = 11.2 Hz, $J_{5'b,4'}$ = 4.9 Hz, H-5′b), 4.21 (td, 1 H, $J_{4',5'a} = J_{4',5'b}$ = 5.2 Hz, $J_{4',3'}$ = 3.4 Hz, H-4′), 4.92 (dd, 1 H, $J_{3',2'}$ = 6.3 Hz, $J_{3',4'}$ = 3.4 Hz, H-3′), 5.25 (dd, 1 H, $J_{2',3'}$ = 6.3 Hz, $J_{2',1'}$ = 2.7 Hz, H-2′), 6.27 (d, 1 H, $J_{1',2'}$ = 2.7 Hz, H-1′), 6.82 (d, 1 H, $J_{5,6}$ = 3.8 Hz, H-5), 7.93 ppm (d, 1 H, $J_{6,5}$ = 3.8 Hz, H-6); MS (ESI) m/z (%): 474 (30) $[M+H]^+$, 496 (100) $[M+Na]^+$; HRMS (ESI) for $C_{20}H_{30}O_4N_3Cl_2Si$ $[M+H]^+$ calcd: 474.13771, found: 474.13784.

General procedure A. Deprotection reactions: Starting material (1 equiv) was treated with aqueous TFA (90% *v/v*, ~1 mL for 250 mg of starting material) at room temperature for 30 min. After completion, the volatiles were removed in vacuo, and the residue co-evaporated several times with MeOH on silica to afford the desired compound.

2-Amino-4-chloro-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (15). Compound **12** (2.42 g, 5.32 mmol) was treated according to general procedure A to give compound **15** as an orange–brown solid (1.6 g, quantitative reaction). No further purification was needed for subsequent steps. Analytical data for compound **15** are in agreement with published data.[18]

2-Methyl-4-chloro-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (16). Compound **13** (3.47 g, 7.65 mmol) was treated according to general procedure A to give compound **16** as a white solid after recrystallization from H_2O/MeOH 4:1 (2.29 g, quantitative reaction): mp: 185–190 °C; $[\alpha]_D^{20}$ = −49.1 (c = 0.222, DMSO); ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): δ = 2.65 (s, 3 H, CH_3-2), 3.56 (ddd, 1 H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 5.6 Hz, $J_{5'a,4'}$ = 3.9 Hz, H-5′a), 3.63 (ddd, 1 H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.1 Hz, $J_{5'b,4'}$ = 4.0 Hz, H-5′b), 3.93 (td, 1 H, $J_{4',5'a} = J_{4',5'b}$ = 3.9 Hz, $J_{4',3'}$ = 3.0 Hz, H-4′), 4.11 (td, 1 H, $J_{3',2'} = J_{3',OH}$ = 4.8 Hz, $J_{3',4'}$ = 3.0 Hz, H-3′), 4.43 (td, 1 H, $J_{2',1'} = J_{2',OH}$ = 6.4 Hz, $J_{2',3'}$ = 5.0 Hz, H-2′), 5.08 (t, 1 H, $J_{OH,5'a} = J_{OH,5'b}$ = 5.4 Hz, OH-5′), 5.20 (d, 1 H, $J_{OH,3'}$ = 4.8 Hz, OH-3′), 5.37 (d, 1 H, $J_{OH,2'}$ = 6.4 Hz, OH-2′), 6.17 (d, 1 H, $J_{1',2'}$ = 6.4 Hz, H-1′), 6.66 (dd, 1 H, $J_{5,6}$ = 3.8 Hz, $J_{5,LR}$ = 0.5 Hz, H-5), 7.87 ppm (d, 1 H, $J_{6,5}$ = 3.8 Hz, H-6); ^{13}C NMR (150.9 MHz, [D$_6$]DMSO): δ = 25.3 (CH_3-2), 61.7 (CH_2-5′), 70.9 (CH-3′), 74.2 (CH-2′), 85.6 (CH-4′), 87.1 (C-1′), 99.7 (CH-5), 115.1 (C-4a), 128.0 (CH-6), 150.7 (C-4), 152.3 (C-7a), 160.2 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3504, 3420, 3117, 1600, 1543, 1465, 1383, 1337, 1288, 1207, 1142, 1122, 1087, 1070, 1062, 1033, 1028, 961, 845, 730, 655 cm^{-1}; MS (ESI) m/z (%): 300 (10) $[M+H]^+$, 322 (100) $[M+Na]^+$; HRMS (ESI) for $C_{12}H_{15}O_3N_3Cl$ $[M+H]^+$ calcd: 300.07456, found: 300.07471; Anal. calcd for $C_{12}H_{14}O_4N_3Cl$: C 48.09, H 4.71, N 14.02, found: C 47.76, H 4.62, N 13.76.

2,4-Dichloro-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (18). Compound **17** (995 mg, 2.10 mmol) was treated according to general procedure A to give compound **18** as a white solid after recrystallization from H_2O/MeOH 4:1 (670 mg, quantitative reaction): mp: 169–171 °C; $[\alpha]_D^{20}$ = −28.4 (c = 0.208, DMSO); ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): δ = 3.57 (ddd, 1 H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 5.1 Hz, $J_{5'a,4'}$ = 3.8 Hz, H-5′a), 3.64 (ddd, 1 H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.1 Hz, $J_{5'b,4'}$ = 4.1 Hz, H-5′b), 3.95 (btd, 1 H, $J_{4',5'a} = J_{4',5'b}$ = 3.9 Hz,

$J_{4',3'}$ = 3.3 Hz, H-4′), 4.11 (btd, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.8 Hz, $J_{3',4'}$ = 3.2 Hz, H-3′), 4.39 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.1 Hz, $J_{2',3'}$ = 5.0 Hz, H-2′), 5.07 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.3 Hz, OH-5′), 5.24 (d, 1H, $J_{OH,3'}$ = 5.0 Hz, OH-3′), 5.45 (d, 1H, $J_{OH,2'}$ = 6.3 Hz, OH-2′), 6.11 (bd, 1H, $J_{1',2'}$ = 6.1 Hz, H-1′), 6.81 (dd, 1H, $J_{5,6}$ = 3.8 Hz, $J_{5,LR}$ = 0.6 Hz, H-5), 8.03 ppm (d, 1H, $J_{6,5}$ = 3.8 Hz, H-6); ^{13}C NMR (150.9 MHz, [D$_6$]DMSO): δ = 61.5 (CH$_2$-5′), 70.7 (CH-3′), 74.5 (CH-2′), 85.8 (CH-4′), 87.3 (C-1′), 100.6 (CH-5), 116.8 (C-4a), 129.6 (CH-6), 150.7 (C-4), 151.5 (C-2), 152.4 ppm (C-7a); IR (ATR): $\tilde{\nu}$ = 3472, 3386, 3154, 3114, 2936, 2920, 1590, 1545, 1504, 1455, 1388, 1287, 1244, 1156, 1087, 1075, 1063, 1030, 892, 738 cm^{-1}; MS (ESI) *m/z* (%): 320 (35) $[M+H]^+$, 342 (100) $[M+Na]^+$; HRMS (ESI) for $C_{11}H_{11}O_4N_3Cl_2Na$ $[M+Na]^+$ calcd: 342.00188, found: 342.00201; Anal. calcd for $C_{11}H_{11}O_4N_3Cl_2$: C 41.27, H 3.46, N 13.13, found: C 41.24, H 3.51, N 12.75.

2-Fluoro-4-chloro-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (19). To a solution of HF·pyridine (70%, 10 mL) at −20 °C was added compound **15** (2 g, 6.65 mmol), followed by *tert*-butyl nitrite (1.19 mL, 9.98 mmol) dropwise. After 30 min of stirring at −20 °C, mixture was diluted with EtOAc (60 mL) and HF neutralized with $CaCO_3$ and aqueous $NaHCO_3$ (sat, 60 mL) to neutral pH. Mixture was filtered on a pad of Celite, and extracted with EtOAc (50 mL). The organic extract was dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica ($CHCl_3$/MeOH, 20:1) to afford **19** (1.26 g, 62%) as a beige solid, after recrystallization from H_2O/MeOH 4:1; mp: 141–145 °C; $[\alpha]_D^{20}$ = −55.0 (*c* = 0.220, DMSO); ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): δ = 3.57 (ddd, 1H, J_{gem} = 12.0 Hz, $J_{5'a,OH}$ = 5.3 Hz, $J_{5'a,4'}$ = 3.8 Hz, H-5′a), 3.65 (ddd, 1H, J_{gem} = 12.0 Hz, $J_{5'b,OH}$ = 5.4 Hz, $J_{5'b,4'}$ = 4.0 Hz, H-5′b), 3.95 (bq, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = $J_{4',3'}$ = 3.6 Hz, H-4′), 4.11 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 5.0 Hz, $J_{3',4'}$ = 3.3 Hz, H-3′), 4.38 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.2 Hz, $J_{2',3'}$ = 5.0 Hz, H-2′), 5.07 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.4 Hz, OH-5′), 5.23 (d, 1H, $J_{OH,3'}$ = 5.0 Hz, OH-3′), 5.45 (d, 1H, $J_{OH,2'}$ = 6.3 Hz, OH-2′), 6.06 (d, 1H, $J_{1',2'}$ = 6.1 Hz, H-1′), 6.81 (dd, 1H, $J_{5,6}$ = 3.8 Hz, $J_{5,LR}$ = 0.6 Hz, H-5), 7.99 ppm (d, 1H, $J_{6,5}$ = 3.8 Hz, H-6); ^{13}C NMR (150.9 MHz, [D$_6$]DMSO): δ = 61.5 (CH$_2$-5′), 70.6 (CH-3′), 74.5 (CH-2′), 85.8 (CH-4′), 87.5 (C-1′), 100.7 (CH-5), 116.4 (d, $J_{C,F}$ = 4.3 Hz, C-4a), 129.3 (d, $J_{C,F}$ = 3.4 Hz, CH-6), 152.1 (d, $J_{C,F}$ = 17.5 Hz, C-7a), 152.9 (d, $J_{C,F}$ = 16.3 Hz, C-4), 156.7 ppm (d, $J_{C,F}$ = 211.4 Hz, C-2); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): δ = −50.24 ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu}$ = 3526, 3450, 3358, 3150, 3137, 3117, 3094, 2945, 2922, 1599, 1571, 1567, 1519, 1469, 1428, 1409, 1372, 1297, 1194, 1094, 1085, 1074, 1049, 1039, 895, 787, 738 cm^{-1}; MS (ESI) *m/z* (%): 326 (100) $[M+Na]^+$. HRMS (ESI) for $C_{11}H_{11}O_4N_3ClFNa$ $[M+Na]^+$ calcd: 326.03143, found: 326.03155; Anal. calcd for $C_{11}H_{11}O_4N_3ClF$: C 43.51, H 3.65, N 13.84, found: C 43.38, H 3.70, N 13.53.

General procedure B. Cross-coupling reactions: An argon-purged mixture of starting material (1 equiv), the appropriate boronic acid (1.5 equiv), Na_2CO_3 (3 equiv), $Pd(OAc)_2$ (0.05 equiv), and 3,3′,3″-phosphanetriyltris(benzenesulfonic acid) trisodium salt (TPPTS; 0.12 equiv) in H_2O/MeCN (2:1; 10 mL per mmol starting material) was stirred at 100 °C for the stated period of time. After cooling, the mixture was neutralized by the addition of aqueous HCl (1 N) and diluted with MeOH (20 mL), volatiles were removed in vacuo, and the residue subjected to chromatography on silica ($CHCl_3$/MeOH, 10:1) to afford the desired compound.

2-Amino-4-(furan-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (5a). Compound **15** (150 mg, 0.5 mmol) was reacted with 2-furylboronic acid (84 mg, 0.75 mmol) for 1 h according to general procedure B to give **5a** as a pale-brown solid (104 mg, 63%) that was recrystallized from H_2O/MeOH (4:1) to provide a tan solid: mp: 152–156 °C; $[\alpha]_D^{20}$ = −46.7 (*c* = 0.152, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 3.52 (ddd, 1H, J_{gem} = 11.8 Hz, $J_{5'a,OH}$ = 5.6 Hz, $J_{5'a,4'}$ = 4.2 Hz, H-5′a), 3.60 (ddd, 1H, J_{gem} = 11.8 Hz, $J_{5'b,OH}$ = 5.4 Hz, $J_{5'b,4'}$ = 4.1 Hz, H-5′b), 3.85 (td, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.2 Hz, $J_{4',3'}$ = 3.2 Hz, H-4′), 4.07 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.9 Hz, $J_{3',4'}$ = 3.2 Hz, H-3′), 4.34 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.4 Hz, $J_{2',3'}$ = 5.2 Hz, H-2′), 5.01 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.5 Hz, OH-5′), 5.09 (d, 1H, $J_{OH,3'}$ = 4.6 Hz, OH-3′), 5.28 (d, 1H, $J_{OH,2'}$ = 6.3 Hz, OH-2′), 6.07 (d, 1H, $J_{1',2'}$ = 6.4 Hz, H-1′), 6.29 (s, 2H, NH_2), 6.72 (dd, 1H, $J_{4,3}$ = 3.4 Hz, $J_{4,5}$ = 1.8 Hz, H-4-furyl), 6.77 (bd, 1H, $J_{5,6}$ = 3.8 Hz, H-5), 7.26 (dd, 1H, $J_{3,4}$ = 3.4 Hz, $J_{3,5}$ = 0.8 Hz, H-3-furyl), 7.38 (d, 1H, $J_{6,5}$ = 3.8 Hz, H-6), 7.97 ppm (dd, 1H, $J_{5,4}$ = 1.8 Hz, $J_{5,3}$ = 0.8 Hz, H-5-furyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 61.9 (CH$_2$-5′), 70.8 (CH-3′), 73.6 (CH-2′), 84.9 (CH-4′), 85.7 (C-1′), 101.6 (CH-5), 106.0 (C-4a), 112.3 (CH-3-furyl), 112.5 (CH-4-furyl), 123.4 (CH-6), 145.6 (CH-5-furyl), 147.5 (C-4), 153.0 (C-2-furyl), 155.3 (C-7a), 159.9 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3128, 1631, 1607, 1577, 1525, 1266 cm^{-1}; MS (ESI) *m/z* (%): 333 (50) $[M+H]^+$, 355 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{16}O_5N_4Na$ $[M+Na]^+$ calcd: 355.10129, found: 355.10122; Anal. calcd for $C_{15}H_{16}O_5N_4 \cdot 1.45\,H_2O$: C 50.26, H 5.31, N 15.63, found: C 50.51, H 5.03, N 15.24.

2-Amino-4-(thien-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (5b). Compound **15** (150 mg, 0.5 mmol) was reacted with 2-thienylboronic acid (96 mg, 0.75 mmol) for 45 min according to general procedure B to give **5b** as a pale-yellow solid (117 mg, 67%) that was recrystallized from H_2O/MeOH 4:1 to provide a yellow solid: mp: 191–197 °C; $[\alpha]_D^{20}$ = −54.9 (*c* = 0.151, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 3.52 (bddd, 1H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 5.6 Hz, $J_{5'a,4'}$ = 4.2 Hz, H-5′a), 3.60 (bddd, 1H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.3 Hz, $J_{5'b,4'}$ = 4.2 Hz, H-5′b), 3.85 (btd, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.2 Hz, $J_{4',3'}$ = 3.3 Hz, H-4′), 4.07 (btd, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.9 Hz, $J_{3',4'}$ = 3.3 Hz, H-3′), 4.35 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.3 Hz, $J_{2',3'}$ = 5.4 Hz, H-2′), 5.02 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.5 Hz, OH-5′), 5.10 (d, 1H, $J_{OH,3'}$ = 4.6 Hz, OH-3′), 5.29 (d, 1H, $J_{OH,2'}$ = 6.3 Hz, OH-2′), 6.08 (d, 1H, $J_{1',2'}$ = 6.3 Hz, H-1′), 6.30 (s, 2H, NH_2), 6.84 (d, 1H, $J_{5,6}$ = 3.9 Hz, H-5), 7.25 (dd, 1H, $J_{4,5}$ = 5.1 Hz, $J_{4,3}$ = 3.8 Hz, H-4-thienyl), 7.42 (d, 1H, $J_{6,5}$ = 3.9 Hz, H-6), 7.76 (dd, 1H, $J_{5,4}$ = 5.1 Hz, $J_{5,3}$ = 1.1 Hz, H-5-thienyl), 8.00 ppm (dd, 1H, $J_{3,4}$ = 3.8 Hz, $J_{3,5}$ = 1.1 Hz, H-3-thienyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 61.9 (CH$_2$-5′), 70.8 (CH-3′), 73.7 (CH-2′), 84.9 (CH-4′), 85.8 (C-1′), 101.2 (CH-5), 106.2 (C-4a), 123.6 (CH-6), 128.8 (CH-4-thienyl), 128.9 (CH-3-thienyl), 129.8 (CH-5-thienyl), 143.3 (C-2-thienyl), 151.1 (C-4), 155.3 (C-7a), 159.6 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3148, 3127, 1581, 1564, 1527, 1261 cm^{-1}; MS (ESI) *m/z* (%): 349 (50) $[M+H]^+$, 371 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{16}O_4N_4NaS$ $[M+Na]^+$ calcd: 371.07845, found: 371.07838; Anal. calcd for $C_{15}H_{16}O_4N_4S \cdot 0.6\,H_2O$: C 50.16, H 4.83, N 15.60, found: C 50.29, H 4.53, N 15.22.

2-Amino-4-(furan-3-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (5c). Compound **15** (150 mg, 0.5 mmol) was reacted with 3-furylboronic acid (84 mg, 0.75 mmol) for 1 h according to general procedure B to give **5c** (82 mg, 50%) as a tan–yellow solid after lyophilization: mp: 148–152 °C; $[\alpha]_D^{20}$ = −41.1 (*c* = 0.180, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 3.52 (m, 1H, J_{gem} = 11.9 Hz, H-5′a), 3.60 (m, 1H, J_{gem} = 11.9 Hz, H-5′b), 3.85 (btd, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.1 Hz, $J_{4',3'}$ = 3.3 Hz, H-4′), 4.07 (m, 1H, H-3′), 4.34 (m, 1H, H-2′), 5.02 (m, 1H, OH-5′), 5.09 (m, 1H, OH-3′), 5.28 (bd, 1H, $J_{OH,2'}$ = 6.1 Hz, OH-2′), 6.06 (d, 1H, $J_{1',2'}$ = 6.4 Hz, H-1′), 6.22 (bs, 2H, NH_2), 6.75 (bd, 1H, $J_{5,6}$ = 3.9 Hz, H-5), 7.10 (dd, 1H, $J_{4,5}$ = 1.9 Hz, $J_{4,2}$ = 0.8 Hz, H-4-furyl), 7.36 (d, 1H, $J_{6,5}$ = 3.9 Hz, H-6), 7.83 (bt, 1H, $J_{5,4}$ = $J_{5,2}$ = 1.7 Hz, H-5-furyl), 8.53 ppm (dd, 1H, $J_{2,5}$ = 1.5 Hz, $J_{2,4}$ = 0.8 Hz, H-2-furyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 61.9 (CH$_2$-5′), 70.8 (CH-3′), 73.7 (CH-2′), 84.8 (CH-4′), 85.8 (C-1′), 101.2 (CH-5), 107.5 (C-4a), 109.6 (CH-4-furyl), 122.9 (CH-6), 125.6 (C-3-furyl), 144.3 (CH-5-furyl), 144.4 (CH-2-furyl), 151.1 (C-4), 154.8 (C-7a), 160.0 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3420, 3155, 3123, 1608, 1587, 1575, 1524, 1510,

1482, 1410, 1352, 1287, 1236, 1197, 1162, 1120, 1100, 1081, 1047, 1023, 987, 897, 873, 668, 630, 598 cm^{-1}; MS (ESI) *m/z* (%): 333 (100) $[M+H]^+$, 355 (30) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{17}O_5N_4$ $[M+H]^+$ calcd: 333.11935, found: 333.11939; Anal. calcd for $C_{15}H_{16}O_5N_4 \cdot 1.15\,H_2O$: C 51.03, H 5.22, N 15.87, found: C 51.24, H 4.94, N 15.55.

2-Amino-4-(thien-3-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (5 d). Compound **15** (150 mg, 0.5 mmol) was reacted with 3-thienylboronic acid (96 mg, 0.75 mmol) for 45 min according to general procedure B to give **5 d** as a colorless oil (111 mg, 64%) that was recrystallized from H_2O/MeOH 4:1 to provide a white solid: mp: 189–194 °C; $[\alpha]_D^{20} = -50.0$ ($c = 0.178$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.52$ (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'a,OH} = 5.6$ Hz, $J_{5'a,4'} = 4.3$ Hz, H-5′a), 3.60 (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'b,OH} = 5.5$ Hz, $J_{5'b,4'} = 4.2$ Hz, H-5′b), 3.85 (btd, 1H, $J_{4',5'a} = J_{4',5'b} = 4.2$ Hz, $J_{4',3'} = 3.2$ Hz, H-4′), 4.08 (btd, 1H, $J_{3',2'} = J_{3',OH} = 4.8$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.35 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.4$ Hz, $J_{2',3'} = 5.2$ Hz, H-2′), 5.02 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.5$ Hz, OH-5′), 5.09 (d, 1H, $J_{OH,3'} = 4.5$ Hz, OH-3′), 5.28 (d, 1H, $J_{OH,2'} = 6.3$ Hz, OH-2′), 6.08 (d, 1H, $J_{1',2'} = 6.4$ Hz, H-1′), 6.25 (s, 2H, NH_2), 6.79 (d, 1H, $J_{5,6} = 3.9$ Hz, H-5), 7.39 (d, 1H, $J_{6,5} = 3.9$ Hz, H-6), 7.68 (dd, 1H, $J_{5,4} = 5.0$ Hz, $J_{5,2} = 2.9$ Hz, H-5-thienyl), 7.81 (dd, 1H, $J_{4,5} = 5.0$ Hz, $J_{4,2} = 1.3$ Hz, H-4-thienyl), 8.33 ppm (dd, 1H, $J_{2,5} = 2.9$ Hz, $J_{2,4} = 1.3$ Hz, H-2-thienyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 61.9$ (CH_2-5′), 70.8 (CH-3′), 73.7 (CH-2′), 84.8 (CH-4′), 85.8 (C-1′), 101.4 (CH-5), 107.6 (C-4a), 123.2 (CH-6), 126.8 (CH-5-thienyl), 127.6 and 127.7 (CH-2,4-thienyl), 140.7 (C-3-thienyl), 152.8 (C-4), 155.2 (C-7a), 159.9 ppm (C-2); IR (ATR): $\tilde{\nu} = 3130$, 3111, 1617, 1587, 1566, 1530, 1261 cm^{-1}; MS (ESI) *m/z* (%): 349 (100) $[M+H]^+$, 371 (50) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{17}O_4N_4S$ $[M+H]^+$ calcd: 349.09650, found: 349.09634; Anal. calcd for $C_{15}H_{16}O_4N_4S$: C 51.71, H 4.63, N 16.08, found: C 51.42, H 4.51, N 15.78.

2-Amino-4-phenyl-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (5 e). Compound **15** (150 mg, 0.5 mmol) was reacted with phenylboronic acid (91 mg, 0.75 mmol) for 30 min according to general procedure B to give **5 e** as a light-yellow oil (138 mg, 81%) that was recrystallized from H_2O/MeOH 4:1 to provide a pale-yellow solid: mp: 132–138 °C; $[\alpha]_D^{20} = -30.3$ ($c = 0.254$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.53$ (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.6$ Hz, $J_{5'a,4'} = 4.2$ Hz, H-5′a), 3.60 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.5$ Hz, $J_{5'b,4'} = 4.2$ Hz, H-5′b), 3.86 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 4.2$ Hz, $J_{4',3'} = 3.2$ Hz, H-4′), 4.08 (td, 1H, $J_{3',2'} = J_{3',OH} = 4.8$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.36 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.4$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.02 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.5$ Hz, OH-5′), 5.10 (d, 1H, $J_{OH,3'} = 4.6$ Hz, OH-3′), 5.29 (d, 1H, $J_{OH,2'} = 6.3$ Hz, OH-2′), 6.11 (d, 1H, $J_{1',2'} = 6.5$ Hz, H-1′), 6.34 (s, 2H, NH_2), 6.66 (bd, 1H, $J_{5,6} = 3.9$ Hz, H-5), 7.40 (d, 1H, $J_{6,5} = 3.9$ Hz, H-6), 7.48–7.57 (m, 3H, H-*p*,*m*-Ph), 8.03 ppm (m, 2H, H-*o*-Ph); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 61.9$ (CH_2-5′), 70.9 (CH-3′), 73.7 (CH-2′), 84.9 (CH-4′), 85.8 (C-1′), 101.3 (CH-5), 108.2 (C-4a), 123.3 (CH-6), 128.5 (CH-*o*-Ph), 128.8 (CH-*m*-Ph), 130.0 (CH-*p*-Ph), 138.3 (C-*i*-Ph), 155.2 (C-7a), 157.5 (C-4), 160.1 ppm (C-2); IR (ATR): $\tilde{\nu} = 3113$, 1622, 1594, 1573, 1525, 1494, 1484, 1448, 1229, 698 cm^{-1}; MS (ESI) *m/z* (%): 343 (100) $[M+H]^+$, 365 (25) $[M+Na]^+$; HRMS (ESI) for $C_{17}H_{19}O_4N_4$ $[M+H]^+$ calcd: 343.14008, found: 343.13992; Anal. calcd for $C_{17}H_{18}O_4N_4 \cdot 1.05\,H_2O$: C 56.52, H 5.61, N 15.51, found: C 56.53, H 5.42, N 15.14.

2-Amino-4-(benzofuran-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo-[2,3-*d*]pyrimidine (5 f). Compound **15** (150 mg, 0.5 mmol) was reacted with 2-benzofurylboronic acid (121 mg, 0.75 mmol) for 2 h according to general procedure B to give **5 f** as a yellow solid (142 mg, 74%) that was recrystallized from H_2O/MeOH 4:1 to provide a yellow solid: mp: 187–193 °C; $[\alpha]_D^{20} = -59.2$ ($c = 0.201$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.54$ (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'a,OH} = 5.6$ Hz, $J_{5'a,4'} = 4.2$ Hz, H-5′a), 3.62 (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'b,OH} = 5.5$ Hz, $J_{5'b,4'} = 4.2$ Hz, H-5′b), 3.87 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 4.2$ Hz, $J_{4',3'} = 3.2$ Hz, H-4′), 4.09 (td, 1H, $J_{3',2'} = J_{3',OH} = 4.9$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.37 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 5.2$ Hz, H-2′), 5.02 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.5$ Hz, OH-5′), 5.12 (d, 1H, $J_{OH,3'} = 4.6$ Hz, OH-3′), 5.32 (d, 1H, $J_{OH,2'} = 6.3$ Hz, OH-2′), 6.11 (d, 1H, $J_{1',2'} = 6.4$ Hz, H-1′), 6.44 (s, 2H, NH_2), 6.97 (d, 1H, $J_{5,6} = 3.9$ Hz, H-5), 7.34 (ddd, 1H, $J_{5,4} = 7.8$ Hz, $J_{5,6} = 7.2$ Hz, $J_{5,7} = 1.0$ Hz, H-5-benzofuryl), 7.44 (ddd, 1H, $J_{6,7} = 8.3$ Hz, $J_{6,5} = 7.2$ Hz, $J_{6,4} = 1.3$ Hz, H-6-benzofuryl), 7.48 (d, 1H, $J_{6,5} = 3.9$ Hz, H-6), 7.72 (d, 1H, $J_{3,7} = 1.0$ Hz, H-3-benzofuryl), 7.76 (dq, 1H, $J_{7,6} = 8.3$ Hz, $J_{7,5} = J_{7,4} = J_{7,3} = 0.9$ Hz, H-7-benzofuryl), 7.79 ppm (ddd, 1H, $J_{4,5} = 7.8$ Hz, $J_{4,6} = 1.3$ Hz, $J_{4,7} = 0.8$ Hz, H-4-benzofuryl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 61.9$ (CH_2-5′), 70.8 (CH-3′), 73.7 (CH-2′), 84.9 (CH-4′), 85.8 (C-1′), 101.8 (CH-5), 107.3 (C-4a), 108.2 (CH-3-benzofuryl), 111.9 (CH-7-benzofuryl), 122.4 (CH-4-benzofuryl), 123.8 (CH-5-benzofuryl), 124.1 (CH-6), 126.3 (CH-6-benzofuryl), 128.0 (C-3a-benzofuryl), 147.3 (C-4), 154.6 (C-2-benzofuryl), 155.1 (C-7a-benzofuryl), 155.6 (C-7a), 160.0 ppm (C-2); IR (ATR): $\tilde{\nu} = 3127$, 1611, 1580, 1550, 1523, 1450, 1256, 1058 cm^{-1}; MS (ESI) *m/z* (%): 383 (60) $[M+H]^+$, 405 (100) $[M+Na]^+$; HRMS (ESI) for $C_{19}H_{18}O_5N_4Na$ $[M+Na]^+$ calcd: 405.11694, found: 405.11691; Anal. calcd for $C_{19}H_{18}O_5N_4 \cdot 0.75\,H_2O$: C 57.64, H 4.96, N 14.15, found: C 57.92, H 4.80, N 13.75.

2-Amino-4-(dibenzofuran-4-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo-[2,3-*d*]pyrimidine (5 g). Compound **15** (150 mg, 0.5 mmol) was reacted with 4-dibenzofurylboronic acid (159 mg, 0.75 mmol) for 30 min according to general procedure B to give **5 g** as a beige solid (183 mg, 85%) that was recrystallized from H_2O/MeOH 4:1 to provide a beige solid: mp: 171–176 °C; $[\alpha]_D^{20} = -37.7$ ($c = 0.276$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.54$ (ddd, 1H, $J_{gem} = 11.7$ Hz, $J_{5'a,OH} = 5.5$ Hz, $J_{5'a,4'} = 4.1$ Hz, H-5′a), 3.61 (ddd, 1H, $J_{gem} = 11.7$ Hz, $J_{5'b,OH} = 5.3$ Hz, $J_{5'b,4'} = 4.1$ Hz, H-5′b), 3.89 (m, 1H, H-4′), 4.09 (btd, 1H, $J_{3',2'} = J_{3',OH} = 4.8$ Hz, $J_{3',4'} = 3.1$ Hz, H-3′), 4.40 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.4$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.02 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.4$ Hz, OH-5′), 5.13 (d, 1H, $J_{OH,3'} = 4.5$ Hz, OH-3′), 5.33 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.15 (d, 1H, $J_{1',2'} = 6.5$ Hz, H-1′), 6.34 (bd, 1H, $J_{5,6} = 3.9$ Hz, H-5), 6.45 (bs, 2H, NH_2), 7.38 (d, 1H, $J_{6,5} = 3.9$ Hz, H-6), 7.45 (btd, 1H, $J_{8,7} = J_{8,9} = 7.5$ Hz, $J_{8,6} = 1.0$ Hz, H-8-$C_{12}H_7O$), 7.54 (ddd, 1H, $J_{7,6} = 8.3$ Hz, $J_{7,8} = 7.3$ Hz, $J_{7,9} = 1.3$ Hz, H-7-$C_{12}H_7O$), 7.56 (t, 1H, $J_{2,1} = J_{2,3} = 7.6$ Hz, H-2-$C_{12}H_7O$), 7.70 (dt, 1H, $J_{6,7} = 8.3$ Hz, $J_{6,8} = J_{6,9} = 0.8$ Hz, H-6-$C_{12}H_7O$), 7.84 (dd, 1H, $J_{3,2} = 7.6$ Hz, $J_{3,1} = 1.3$ Hz, H-3-$C_{12}H_7O$), 8.23 (ddd, 1H, $J_{9,8} = 7.7$ Hz, $J_{9,7} = 1.3$ Hz, $J_{9,6} = 0.7$ Hz, H-9-$C_{12}H_7O$), 8.30 ppm (dd, 1H, $J_{1,2} = 7.7$ Hz, $J_{1,3} = 1.3$ Hz, H-1-$C_{12}H_7O$); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 62.0$ (CH_2-5′), 70.9 (CH-3′), 73.7 (CH-2′), 85.0 (CH-4′), 85.8 (C-1′), 101.9 (CH-5), 110.2 (C-4a), 112.0 (CH-6-$C_{12}H_7O$), 121.5 (CH-9-$C_{12}H_7O$), 122.4 (CH-1-$C_{12}H_7O$), 123.0 (CH-6), 123.3 (CH-4-$C_{12}H_7O$), 123.4 (CH-2,8-$C_{12}H_7O$), 123.5 (C-9a-$C_{12}H_7O$), 124.7 (C-9b-$C_{12}H_7O$), 128.1 (CH-7-$C_{12}H_7O$), 128.4 (CH-3-$C_{12}H_7O$), 152.8 (C-4a-$C_{12}H_7O$), 154.8 (C-7a), 154.9 (C-4), 155.7 (C-5a-$C_{12}H_7O$), 160.3 ppm (C-2); IR (ATR): $\tilde{\nu} = 1619$, 1592, 1582, 1568, 1452, 1284, 1193 cm^{-1}; MS (ESI) *m/z* (%): 433 (100) $[M+H]^+$, 455 (20) $[M+Na]^+$; HRMS (ESI) for $C_{23}H_{21}O_5N_4$ $[M+H]^+$ calcd: 433.15065, found: 433.15066; Anal. calcd for $C_{23}H_{20}O_5N_4 \cdot 1.2\,H_2O$: C 60.84, H 4.97, N 12.34, found: C 60.83, H 4.66, N 12.04.

2-Methyl-4-(furan-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (6 a). Compound **16** (150 mg, 0.5 mmol) was reacted with 2-furylboronic acid (84 mg, 0.75 mmol) for 10 min according to general procedure B to give **6 a** as a light-yellow oil (131 mg, 79%) that was recrystallized from H_2O/MeOH 4:1 to provide a beige solid: mp: 231–236 °C; $[\alpha]_D^{20} = -62.3$ ($c = 0.199$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 2.67$ (s, 3H, CH_3), 3.56 (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'a,OH} = 6.0$ Hz, $J_{5'a,4'} = 3.9$ Hz, H-5′a), 3.64 (ddd, 1H,

J_{gem} = 11.8 Hz, $J_{5'b,OH}$ = 5.2 Hz, $J_{5'b,4'}$ = 3.9 Hz, H-5′b), 3.93 (td, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 3.9 Hz, $J_{4',3'}$ = 3.0 Hz, H-4′), 4.11 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.9 Hz, $J_{3',4'}$ = 3.0 Hz, H-3′), 4.46 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.5 Hz, $J_{2',3'}$ = 5.1 Hz, H-2′), 5.14 (dd, 1H, $J_{OH,5'a}$ = 6.0 Hz, $J_{OH,5'b}$ = 5.2 Hz, OH-5′), 5.19 (d, 1H, $J_{OH,3'}$ = 4.7 Hz, OH-3′), 5.35 (d, 1H, $J_{OH,2'}$ = 6.5 Hz, OH-2′), 6.20 (d, 1H, $J_{1',2'}$ = 6.5 Hz, H-1′), 6.77 (dd, 1H, $J_{4,3}$ = 3.5 Hz, $J_{4,5}$ = 1.8 Hz, H-4-furyl), 6.99 (bd, 1H, $J_{5,6}$ = 3.8 Hz, H-5), 7.43 (dd, 1H, $J_{3,4}$ = 3.5 Hz, $J_{3,5}$ = 0.9 Hz, H-3-furyl), 7.81 (d, 1H, $J_{6,5}$ = 3.8 Hz, H-6), 8.04 ppm (dd, 1H, $J_{5,4}$ = 1.8 Hz, $J_{5,3}$ = 0.8 Hz, H-5-furyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 25.8 (CH_3), 61.9 (CH_2-5′), 71.0 (CH-3′), 73.9 (CH-2′), 85.5 (CH-4′), 86.7 (C-1′), 101.2 (CH-5), 110.7 (C-4a), 112.8 (CH-4-furyl), 113.2 (CH-3-furyl), 127.6 (CH-6), 146.3 (CH-5-furyl), 146.6 (C-4), 152.7 (C-2-furyl), 153.2 (C-7a), 160.0 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3143, 3127, 2927, 2910, 1602, 1568, 1517, 1254 cm^{-1}; MS (ESI) *m/z* (%): 332 (100) $[M+H]^+$; HRMS (ESI) for $C_{16}H_{18}O_5N_3$ $[M+H]^+$ calcd: 332.12410, found: 332.12418; Anal. calcd for $C_{16}H_{17}O_5N_3 \cdot 0.4H_2O$: C 56.77, H 5.30, N 12.41, found: C 57.08, H 5.18, N 12.11.

2-Methyl-4-(thien-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (6b). Compound **16** (150 mg, 0.5 mmol) was reacted with 2-thienylboronic acid (96 mg, 0.75 mmol) for 15 min according to general procedure B to give **6b** as a beige solid (169 mg, 97%) that was recrystallized from H_2O/MeOH 4:1 to provide a beige solid: mp: 204–206 °C; $[\alpha]_D^{20}$ = −64.5 (*c* = 0.244, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 2.66 (s, 3H, CH_3), 3.56 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 5.8 Hz, $J_{5'a,4'}$ = 3.8 Hz, H-5′a), 3.64 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.3 Hz, $J_{5'b,4'}$ = 4.1 Hz, H-5′b), 3.93 (btd, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.0 Hz, $J_{4',3'}$ = 3.0 Hz, H-4′), 4.12 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.9 Hz, $J_{3',4'}$ = 3.0 Hz, H-3′), 4.47 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.4 Hz, $J_{2',3'}$ = 5.3 Hz, H-2′), 5.14 (bt, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.5 Hz, OH-5′), 5.20 (d, 1H, $J_{OH,3'}$ = 4.7 Hz, OH-3′), 5.36 (d, 1H, $J_{OH,2'}$ = 6.4 Hz, OH-2′), 6.21 (d, 1H, $J_{1',2'}$ = 6.5 Hz, H-1′), 7.10 (d, 1H, $J_{5,6}$ = 3.8 Hz, H-5), 7.29 (dd, 1H, $J_{4,5}$ = 5.1 Hz, $J_{4,3}$ = 3.8 Hz, H-4-thienyl), 7.83 (dd, 1H, $J_{5,4}$ = 5.1 Hz, $J_{5,3}$ = 1.1 Hz, H-5-thienyl), 7.84 (d, 1H, $J_{6,5}$ = 3.9 Hz, H-6), 8.14 ppm (dd, 1H, $J_{3,4}$ = 3.8 Hz, $J_{3,5}$ = 1.1 Hz, H-3-thienyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 25.7 (CH_3), 61.9 (CH_2-5′), 70.9 (CH-3′), 74.0 (CH-2′), 84.5 (CH-4′), 86.7 (C-1′), 100.8 (CH-5), 110.9 (C-4a), 127.7 (CH-6), 129.1 (CH-4-thienyl), 129.6 (CH-3-thienyl), 130.7 (CH-5-thienyl), 142.8 (C-2-thienyl), 150.2 (C-4), 153.2 (C-7a), 159.7 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3139, 3114, 2922, 2830, 1565, 1517, 1271 cm^{-1}; MS (ESI) *m/z* (%): 348 (85) $[M+H]^+$, 370 (100) $[M+Na]^+$; HRMS (ESI) for $C_{16}H_{18}O_4N_3S$ $[M+H]^+$ calcd: 348.10125, found: 348.10064; Anal. calcd for $C_{16}H_{17}O_4N_3S \cdot 0.15H_2O$: C 54.89, H 4.98, N 12.00, found: C 55.26, H 4.91, N 11.61.

2-Methyl-4-(furan-3-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (6c). Compound **16** (150 mg, 0.5 mmol) was reacted with 3-furylboronic acid (84 mg, 0.75 mmol) for 15 min according to general procedure B to give **6c** as a light-yellow oil (162 mg, 98%) that was recrystallized from H_2O/MeOH 4:1 to provide beige needles: mp: 191–193 °C; $[\alpha]_D^{20}$ = −55.9 (*c* = 0.227, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 2.67 (s, 3H, CH_3), 3.56 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 6.0 Hz, $J_{5'a,4'}$ = 4.0 Hz, H-5′a), 3.64 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.2 Hz, $J_{5'b,4'}$ = 4.0 Hz, H-5′b), 3.93 (td, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 3.9 Hz, $J_{4',3'}$ = 3.0 Hz, H-4′), 4.12 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.9 Hz, $J_{3',4'}$ = 3.0 Hz, H-3′), 4.47 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.5 Hz, $J_{2',3'}$ = 5.1 Hz, H-2′), 5.15 (dd, 1H, $J_{OH,5'a}$ = 6.0 Hz, $J_{OH,5'b}$ = 5.1 Hz, OH-5′), 5.19 (d, 1H, $J_{OH,3'}$ = 4.9 Hz, OH-3′), 5.34 (d, 1H, $J_{OH,2'}$ = 6.5 Hz, OH-2′), 6.20 (d, 1H, $J_{1',2'}$ = 6.5 Hz, H-1′), 7.01 (bd, 1H, $J_{5,6}$ = 3.9 Hz, H-5), 7.23 (dd, 1H, $J_{4,5}$ = 1.9 Hz, $J_{4,2}$ = 0.8 Hz, H-4-furyl), 7.79 (d, 1H, $J_{6,5}$ = 3.9 Hz, H-6), 7.88 (bt, 1H, $J_{5,4}$ = $J_{5,2}$ = 1.7 Hz, H-5-furyl), 8.68 ppm (dd, 1H, $J_{2,5}$ = 1.5 Hz, $J_{2,4}$ = 0.8 Hz, H-2-furyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 25.9 (CH_3), 61.9 (CH_2-5′), 70.9 (CH-3′), 73.9 (CH-2′), 85.4 (CH-4′), 86.7 (C-1′), 100.7 (CH-5), 109.6 (CH-4-furyl), 112.4 (C-4a), 125.3 (CH-3-furyl), 127.1 (CH-6), 144.7 (CH-5-furyl), 144.9 (C-2-furyl), 150.1 (C-4), 152.7 (C-7a), 159.9 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3152, 3119, 1598, 1568, 1552, 1511, 1460, 1407, 1366, 1255, 1243, 1199, 1162, 1066, 965, 871, 768, 723, 641, 604 cm^{-1}; MS (ESI) *m/z* (%): 332 (90) $[M+H]^+$, 354 (100) $[M+Na]^+$; HRMS (ESI) for $C_{16}H_{17}O_5N_3Na$ $[M+Na]^+$ calcd: 354.10604, found: 354.10575; Anal. calcd for $C_{16}H_{17}O_5N_3$: C 58.00, H 5.17, N 12.68, found: C 57.94, H 5.08, N 12.54.

2-Methyl-4-(thien-3-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (6d). Compound **16** (150 mg, 0.5 mmol) was reacted with 2-thienylboronic acid (96 mg, 0.75 mmol) for 10 min according to general procedure B to give **6d** as a beige solid (158 mg, 91%) that was recrystallized from H_2O/MeOH 4:1 to provide a beige solid: mp: 213–216 °C; $[\alpha]_D^{20}$ = −59.5 (*c* = 0.237, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 2.69 (s, 3H, CH_3), 3.56 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 6.0 Hz, $J_{5'a,4'}$ = 4.0 Hz, H-5′a), 3.64 (ddd, 1H, J_{gem} = 11.8 Hz, $J_{5'b,OH}$ = 5.2 Hz, $J_{5'b,4'}$ = 4.0 Hz, H-5′b), 3.93 (td, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.0 Hz, $J_{4',3'}$ = 3.1 Hz, H-4′), 4.12 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.9 Hz, $J_{3',4'}$ = 3.1 Hz, H-3′), 4.47 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.5 Hz, $J_{2',3'}$ = 5.2 Hz, H-2′), 5.14 (dd, 1H, $J_{OH,5'a}$ = 6.0 Hz, $J_{OH,5'b}$ = 5.2 Hz, OH-5′), 5.19 (d, 1H, $J_{OH,3'}$ = 4.7 Hz, OH-3′), 5.35 (d, 1H, $J_{OH,2'}$ = 6.5 Hz, OH-2′), 6.22 (d, 1H, $J_{1',2'}$ = 6.6 Hz, H-1′), 7.05 (d, 1H, $J_{5,6}$ = 3.8 Hz, H-5), 7.73 (dd, 1H, $J_{5,4}$ = 5.1 Hz, $J_{5,2}$ = 2.9 Hz, H-5-thienyl), 7.82 (d, 1H, $J_{6,5}$ = 3.8 Hz, H-6), 7.93 (dd, 1H, $J_{4,5}$ = 5.1 Hz, $J_{4,2}$ = 1.3 Hz, H-4-thienyl), 8.49 ppm (dd, 1H, $J_{2,5}$ = 2.9 Hz, $J_{2,4}$ = 1.3 Hz, H-2-thienyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 25.9 (CH_3), 61.9 (CH_2-5′), 71.0 (CH-3′), 73.9 (CH-2′), 85.4 (CH-4′), 86.7 (C-1′), 101.0 (CH-5), 112.5 (C-4a), 127.2 (CH-5-thienyl), 127.4 (CH-6), 127.7 (CH-4-thienyl), 128.5 (CH-2-thienyl), 140.2 (C-3-thienyl), 151.6 (C-4), 153.1 (C-7a), 159.8 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3426, 3115, 3101, 2924, 1572, 1566, 1518, 1464, 1405, 1367, 1348, 1289, 1241, 1176, 1116, 1079, 1052, 1044, 969, 898, 842, 770, 720, 688, 609 cm^{-1}; MS (ESI) *m/z* (%): 348 (100) $[M+H]^+$, 370 (80) $[M+Na]^+$; HRMS (ESI) for $C_{16}H_{18}O_4N_3S$ $[M+H]^+$ calcd: 348.10125, found: 348.10126; Anal. calcd for $C_{16}H_{17}O_4N_3S \cdot 0.1H_2O$: C 55.03, H 4.96, N 12.03, found: C 55.56, H 5.04, N 11.53.

2-Methyl-4-phenyl-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (6e). Compound **16** (150 mg, 0.5 mmol) was reacted with phenylboronic acid (91 mg, 0.75 mmol) for 10 min according to general procedure B to give **6e** as a colorless oil (126 mg, 74%) that was recrystallized from H_2O/MeOH 4:1 to provide a white solid: mp: 92–95 °C; $[\alpha]_D^{20}$ = −51.1 (*c* = 0.217, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 2.73 (s, 3H, CH_3), 3.56 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 5.9 Hz, $J_{5'a,4'}$ = 3.9 Hz, H-5′a), 3.64 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.1 Hz, $J_{5'b,4'}$ = 4.0 Hz, H-5′b), 3.94 (td, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.0 Hz, $J_{4',3'}$ = 3.0 Hz, H-4′), 4.13 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.9 Hz, $J_{3',4'}$ = 3.0 Hz, H-3′), 4.49 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.5 Hz, $J_{2',3'}$ = 5.1 Hz, H-2′), 5.13 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.5 Hz, OH-5′), 5.20 (d, 1H, $J_{OH,3'}$ = 4.7 Hz, OH-3′), 5.36 (d, 1H, $J_{OH,2'}$ = 6.5 Hz, OH-2′), 6.24 (d, 1H, $J_{1',2'}$ = 6.5 Hz, H-1′), 6.92 (d, 1H, $J_{5,6}$ = 3.8 Hz, H-5), 7.53–7.61 (m, 3H, H-*p*,*m*-Ph), 7.83 (d, 1H, $J_{6,5}$ = 3.8 Hz, H-6), 8.14 ppm (m, 2H, H-*o*-Ph); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 25.9 (CH_3), 61.9 (CH_2-5′), 71.0 (CH-3′), 74.0 (CH-2′), 85.5 (CH-4′), 86.7 (CH-1′), 100.9 (CH-5), 113.4 (C-4a), 127.5 (CH-6), 128.8 (CH-*o*-Ph), 129.1 (CH-*m*-Ph), 130.3 (CH-*p*-Ph), 137.9 (C-*i*-Ph), 153.1 (C-7a), 156.3 (C-4), 160.0 ppm (C-2); IR (ATR): $\tilde{\nu}$ = 3430, 3070, 2928, 1606, 1587, 1496, 1466, 1404, 1361, 1287, 1270, 1237, 1125, 1114, 1087, 1078, 1044, 1030, 1002, 898, 883, 694, 668 cm^{-1}; MS (ESI) *m/z* (%): 342 (100) $[M+H]^+$, 364 (25) $[M+Na]^+$; HRMS (ESI) for $C_{18}H_{20}O_4N_3$ $[M+H]^+$ calcd: 342.14483, found: 342.14487; Anal. calcd for $C_{18}H_{19}O_4N_3 \cdot 1.8H_2O$: C 57.84, H 6.09, N 11.24, found: C 58.09, H 6.03, N 10.94.

2-Methyl-4-(benzofuran-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo-[2,3-*d*]pyrimidine (6f). Compound **16** (150 mg, 0.5 mmol) was reacted with 2-benzofurylboronic acid (121 mg, 0.75 mmol) for

30 min according to general procedure B to give **6f** as a white solid (151 mg, 79%) that was recrystallized from H_2O/MeOH 4:1 to provide a white solid: mp: 242–244 °C; $[\alpha]_D^{20} = -70.4$ ($c = 0.240$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 2.73$ (s, 3H, CH_3), 3.57 (m, 1H, H-5′a), 3.66 (m, 1H, H-5′b), 3.95 (m, 1H, H-4′), 4.14 (m, 1H, H-3′), 4.49 (bq, 1H, $J_{2',1'} = J_{2',OH} = J_{2',3'} = 5.9$ Hz, H-2′), 5.14 (bt, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.5$ Hz, OH-5′), 5.22 (bd, 1H, $J_{OH,3'} = 4.7$ Hz, OH-3′), 5.39 (bd, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.24 (d, 1H, $J_{1',2'} = 6.6$ Hz, H-1′), 7.21 (d, 1H, $J_{5,6} = 3.7$ Hz, H-5), 7.36 (bt, 1H, $J_{5,4} = J_{5,6} = 7.6$ Hz, H-5-benzofuryl), 7.47 (bt, 1H, $J_{6,7} = J_{6,5} = 8.0$ Hz, H-6-benzofuryl), 7.78–7.84 (m, 2H, H-4,7-benzofuryl), 7.90 (bs, 1H, H-3-benzofuryl), 7.91 ppm (d, 1H, $J_{6,5} = 3.7$ Hz, H-6); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 25.8$ (CH_3), 61.9 (CH_2-5′), 70.9 (CH-3′), 74.0 (CH-2′), 85.5 (CH-4′), 86.7 (CH-1′), 101.5 (CH-5), 109.1 (CH-3-benzofuryl), 112.0 (C-4a), 112.1 (CH-7-benzofuryl), 122.6 (CH-4-benzofuryl), 123.9 (CH-5-benzofuryl), 126.6 (CH-6-benzofuryl), 128.0 (C-3a-benzofuryl), 128.2 (CH-6), 146.4 (C-4), 153.5 (C-7a), 154.3 (C-2-benzofuryl), 155.4 (C-7a-benzofuryl), 160.1 ppm (C-2); IR (ATR): $\tilde{\nu} = 3471$, 3371, 3226, 1599, 1569, 1548, 1515, 1480, 1455, 1365, 1273, 1256, 1248, 1149, 1131, 1041, 987, 975, 892, 848, 737, 724, 664, 605 cm^{-1}; MS (ESI) *m/z* (%): 382 (100) $[M+H]^+$, 404 (75) $[M+Na]^+$; HRMS (ESI) for $C_{20}H_{20}O_5N_3$ $[M+H]^+$ calcd: 382.13975, found: 382.13979; Anal. calcd for $C_{20}H_{19}O_5N_3 \cdot 0.2\,H_2O$: C 62.40, H 5.08, N 10.91, found: C 62.78, H 5.20, N 10.43.

2-Methyl-4-(dibenzofuran-4-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (6g). Compound **16** (150 mg, 0.5 mmol) was reacted with 4-dibenzofurylboronic acid (159 mg, 0.75 mmol) for 15 min according to general procedure B to give **6g** as a colorless oil (142 mg, 66%) that was lyophilized to provide a white solid: mp: 206–210 °C; $[\alpha]_D^{20} = -47.2$ ($c = 0.176$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 2.78$ (s, 3H, CH_3), 3.58 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.9$ Hz, $J_{5'a,4'} = 3.9$ Hz, H-5′a), 3.66 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.1$ Hz, $J_{5'b,4'} = 4.1$ Hz, H-5′b), 3.97 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 4.0$ Hz, $J_{4',3'} = 2.8$ Hz, H-4′), 4.15 (td, 1H, $J_{3',2'} = J_{3',OH} = 4.9$ Hz, $J_{3',4'} = 2.8$ Hz, H-3′), 4.53 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.6$ Hz, $J_{2',3'} = 5.0$ Hz, H-2′), 5.15 (bt, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.5$ Hz, OH-5′), 5.23 (d, 1H, $J_{OH,3'} = 4.7$ Hz, OH-3′), 5.41 (d, 1H, $J_{OH,2'} = 6.5$ Hz, OH-2′), 6.30 (d, 1H, $J_{1',2'} = 6.6$ Hz, H-1′), 6.63 (d, 1H, $J_{5,6} = 3.8$ Hz, H-5), 7.46 (td, 1H, $J_{8,7} = J_{8,9} = 7.5$ Hz, $J_{8,6} = 1.0$ Hz, H-8-$C_{12}H_7O$), 7.55 (ddd, 1H, $J_{7,6} = 8.3$ Hz, $J_{7,8} = 7.3$ Hz, $J_{7,9} = 1.4$ Hz, H-7-$C_{12}H_7O$), 7.60 (t, 1H, $J_{2,1} = J_{2,3} = 7.6$ Hz, H-2-$C_{12}H_7O$), 7.70 (dt, 1H, $J_{6,7} = 8.2$ Hz, $J_{6,8} = J_{6,9} = 0.8$ Hz, H-6-$C_{12}H_7O$), 7.83 (d, 1H, $J_{6,5} = 3.8$ Hz, H-6), 7.94 (dd, 1H, $J_{3,2} = 7.6$ Hz, $J_{3,1} = 1.3$ Hz, H-3-$C_{12}H_7O$), 8.25 (ddd, 1H, $J_{9,8} = 7.7$ Hz, $J_{9,7} = 1.3$ Hz, $J_{9,6} = 0.6$ Hz, H-9-$C_{12}H_7O$), 8.35 ppm (dd, 1H, $J_{1,2} = 7.7$ Hz, $J_{1,3} = 1.3$ Hz, H-1-$C_{12}H_7O$); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 25.9$ (CH_3), 62.0 (CH_2-5′), 71.1 (CH-3′), 74.0 (CH-2′), 85.6 (CH-4′), 86.6 (CH-1′), 101.7 (CH-5), 112.0 (CH-6-$C_{12}H_7O$), 115.4 (C-4a), 121.6 (CH-9-$C_{12}H_7O$), 122.8 (C-4-$C_{12}H_7O$), 122.9 (CH-1-$C_{12}H_7O$), 123.5 (C-9a-$C_{12}H_7O$), 123.6 (CH-2,8-$C_{12}H_7O$), 124.8 (C-9b-$C_{12}H_7O$), 127.1 (CH-6), 128.2 (CH-7-$C_{12}H_7O$), 128.7 (CH-3-$C_{12}H_7O$), 152.7 (C-7a), 152.9 (C-4a-$C_{12}H_7O$), 153.7 (C-4), 155.2 (C-5a-$C_{12}H_7O$), 160.2 ppm (C-2); IR (ATR): $\tilde{\nu} = 3412$, 3116, 1605, 1563, 1517, 1511, 1493, 1461, 1453, 1287, 1258, 1240, 1116, 1080, 1054, 1041, 992, 894, 840, 731, 602 cm^{-1}; MS (ESI) *m/z* (%): 432 (100) $[M+H]^+$, 454 (60) $[M+Na]^+$; HRMS (ESI) for $C_{24}H_{22}O_5N_3$ $[M+H]^+$ calcd: 432.15540, found: 432.15541; Anal. calcd for $C_{24}H_{21}O_5N_3 \cdot 0.45\,H_2O$: C 65.58, H 5.02, N 9.56, found: C 65.83, H 4.91, N 9.22.

2-Chloro-4-(furan-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (7a). Compound **18** (160 mg, 0.5 mmol) was reacted with 2-furylboronic acid (61 mg, 0.55 mmol) for 10 min according to general procedure B (only one-half quantities for catalysts) to give **7a** as a white solid (145 mg, 82%) that was recrystallized from H_2O/MeOH 4:1 to provide white needles: mp: 205–210 °C; $[\alpha]_D^{20} = -60.0$ ($c = 0.190$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.57$ (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.4$ Hz, $J_{5'a,4'} = 4.0$ Hz, H-5′a), 3.64 (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.0$ Hz, H-5′b), 3.94 (btd, 1H, $J_{4',5'a} = J_{4',5'b} = 4.0$ Hz, $J_{4',3'} = 3.2$ Hz, H-4′), 4.11 (btd, 1H, $J_{3',2'} = J_{3',OH} = 5.0$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.41 (btd, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.06 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.4$ Hz, OH-5′), 5.24 (d, 1H, $J_{OH,3'} = 4.9$ Hz, OH-3′), 5.44 (d, 1H, $J_{OH,2'} = 6.3$ Hz, OH-2′), 6.14 (d, 1H, $J_{1',2'} = 6.3$ Hz, H-1′), 6.82 (dd, 1H, $J_{4,3} = 3.6$ Hz, $J_{4,5} = 1.7$ Hz, H-4-furyl), 7.10 (bd, 1H, $J_{5,6} = 3.8$ Hz, H-5), 7.54 (dd, 1H, $J_{3,4} = 3.6$ Hz, $J_{3,5} = 0.8$ Hz, H-3-furyl), 7.97 (d, 1H, $J_{6,5} = 3.8$ Hz, H-6), 8.11 ppm (dd, 1H, $J_{5,4} = 1.7$ Hz, $J_{5,3} = 0.8$ Hz, H-5-furyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): 61.7 (CH_2-5′), $\delta = 70.8$ (CH-3′), 74.3 (CH-2′), 85.7 (CH-4′), 86.7 (C-1′), 102.0 (CH-5), 111.8 (C-4a), 113.3 (CH-4-furyl), 115.2 (CH-3-furyl), 128.9 (CH-6), 147.5 (CH-5-furyl), 148.2 (C-4), 151.3 (C-2-furyl), 152.5 (C-2), 153.7 ppm (C-7a); IR (ATR): $\tilde{\nu} = 1598$, 1562, 1513, 1253 cm^{-1}; MS (ESI) *m/z* (%): 352 (10) $[M+H]^+$, 374 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{14}O_5N_3ClNa$ $[M+Na]^+$ calcd: 374.05142, found: 374.05136; Anal. calcd for $C_{15}H_{14}O_5N_3Cl \cdot 0.3\,H_2O$: C 50.44, H 4.12, N 11.77, found: C 50.54, H 3.98, N 11.58.

2-Chloro-4-(thien-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (7b). Compound **18** (160 mg, 0.5 mmol) was reacted with 2-thienylboronic acid (70 mg, 0.55 mmol) for 10 min according to general procedure B (only one-half quantities for catalysts) to give **7b** as a light-yellow oil (103 mg, 56%) that was recrystallized from H_2O/MeOH 4:1 to provide a beige solid: mp: 94–99 °C; $[\alpha]_D^{20} = -48.7$ ($c = 0.228$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.57$ (ddd, 1H, $J_{gem} = 12.0$ Hz, $J_{5'a,OH} = 5.5$ Hz, $J_{5'a,4'} = 3.9$ Hz, H-5′a), 3.65 (ddd, 1H, $J_{gem} = 12.0$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.0$ Hz, H-5′b), 3.95 (btd, 1H, $J_{4',5'a} = J_{4',5'b} = 3.9$ Hz, $J_{4',3'} = 3.2$ Hz, H-4′), 4.12 (td, 1H, $J_{3',2'} = J_{3',OH} = 5.0$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.42 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.07 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.5$ Hz, OH-5′), 5.24 (d, 1H, $J_{OH,3'} = 5.0$ Hz, OH-3′), 5.44 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.15 (d, 1H, $J_{1',2'} = 6.3$ Hz, H-1′), 7.24 (bd, 1H, $J_{5,6} = 3.8$ Hz, H-5), 7.33 (dd, 1H, $J_{4,5} = 5.0$ Hz, $J_{4,3} = 3.8$ Hz, H-4-thienyl), 7.95 (dd, 1H, $J_{5,4} = 5.0$ Hz, $J_{5,3} = 1.1$ Hz, H-5-thienyl), 8.00 (d, 1H, $J_{6,5} = 3.9$ Hz, H-6), 8.23 ppm (dd, 1H, $J_{3,4} = 3.9$ Hz, $J_{3,5} = 1.1$ Hz, H-3-thienyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 61.6$ (CH_2-5′), 70.8 (CH-3′), 74.3 (CH-2′), 85.7 (CH-4′), 86.8 (C-1′), 101.7 (CH-5), 112.2 (C-4a), 129.0 (CH-6), 129.5 (CH-4-thienyl), 131.1 (CH-3-thienyl), 132.3 (CH-5-thienyl), 140.8 (C-2-thienyl), 152.1 and 152.3 (C-2,4), 153.6 ppm (C-7a); IR (ATR): $\tilde{\nu} = 3113$, 3077, 1615, 1561, 1509, 1432, 1428, 1362, 1350, 1296, 1182, 1117, 1082, 1048, 986, 896, 853, 808, 468 cm^{-1}; MS (ESI) *m/z* (%): 368 (5) $[M+H]^+$, 390 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{14}O_4N_3ClNaS$ $[M+Na]^+$ calcd: 390.02858, found: 390.02865; Anal. calcd for $C_{15}H_{14}O_4N_3ClS \cdot 2\,H_2O$: C 44.61, H 4.49, N 10.41, found: C 44.54, H 4.32, N 10.12.

2-Chloro-4-(furan-3-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (7c). Compound **18** (160 mg, 0.5 mmol) was reacted with 3-furylboronic acid (61 mg, 0.55 mmol) for 10 min according to general procedure B (only one-half quantities for catalysts) to give **7c** as a yellow oil (138 mg, 78%) that was lyophilized to provide a brown solid: mp: 89–93 °C; $[\alpha]_D^{20} = -37.2$ ($c = 0.251$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.57$ (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.5$ Hz, $J_{5'a,4'} = 4.0$ Hz, H-5′a), 3.65 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.2$ Hz, H-5′b), 3.94 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 4.1$ Hz, $J_{4',3'} = 3.1$ Hz, H-4′), 4.12 (td, 1H, $J_{3',2'} = J_{3',OH} = 5.0$ Hz, $J_{3',4'} = 3.1$ Hz, H-3′), 4.42 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.06 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.5$ Hz, OH-5′), 5.23 (d, 1H, $J_{OH,3'} = 5.0$ Hz, OH-3′), 5.43 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.14 (d, 1H, $J_{1',2'} = 6.3$ Hz, H-1′), 7.17 (dd, 1H, $J_{5,6} = 3.9$ Hz, $J_{5,LR} = 0.4$ Hz, H-5), 7.23 (dd, 1H,

$J_{4,5}$ = 1.9 Hz, $J_{4,2}$ = 0.9 Hz, H-4-furyl), 7.93 (dd, 1H, $J_{5,4}$ = 1.9 Hz, $J_{5,2}$ = 1.5 Hz, H-5-furyl), 7.96 (d, 1H, $J_{6,5}$ = 3.9 Hz, H-6), 8.79 ppm (dd, 1H, $J_{2,5}$ = 1.5 Hz, $J_{2,4}$ = 0.8 Hz, H-2-furyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 61.7 (CH_2-5′), 70.8 (CH-3′), 74.3 (CH-2′), 85.6 (CH-4′), 86.7 (C-1′), 101.5 (CH-5), 109.4 (CH-4-furyl), 113.7 (C-4a), 124.5 (C-3-furyl), 128.5 (CH-6), 145.2 (CH-5-furyl), 146.1 (CH-2-furyl), 152.3 and 152.5 (C-2,4), 153.2 ppm (C-7a); IR (ATR): $\tilde{\nu}$ = 3405, 3154, 1594, 1567, 1509, 1260, 1197, 1165, 1093, 1083, 1052, 1036, 965, 872, 721, 648, 599 cm^{-1}; MS (ESI) *m/z* (%): 352 (5) $[M+H]^+$, 374 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{14}O_5N_3ClNa$ $[M+Na]^+$ calcd: 374.05142, found: 374.05153; Anal. calcd for $C_{15}H_{14}O_5N_3Cl\cdot0.85\,H_2O$: C 49.08, H 4.31, N 11.45, found: C 49.24, H 4.07, N 11.23.

2-Chloro-4-(thien-3-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (7 d). Compound **18** (160 mg, 0.5 mmol) was reacted with 3-thienylboronic acid (70 mg, 0.55 mmol) for 10 min according to general procedure B (only one-half quantities for catalysts) to give **7 d** as a beige solid (107 mg, 58%) that was lyophilized to provide a beige solid: mp: 179–183 °C; $[\alpha]_D^{20}$ = −44.9 (*c* = 0.247, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 3.57 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 5.5 Hz, $J_{5'a,4'}$ = 4.0 Hz, H-5′a), 3.65 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.5 Hz, $J_{5'b,4'}$ = 4.1 Hz, H-5′b), 3.94 (td, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.0 Hz, $J_{4',3'}$ = 3.2 Hz, H-4′), 4.12 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 5.0 Hz, $J_{3',4'}$ = 3.2 Hz, H-3′), 4.42 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.4 Hz, $J_{2',3'}$ = 5.1 Hz, H-2′), 5.06 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.5 Hz, OH-5′), 5.24 (d, 1H, $J_{OH,3'}$ = 5.0 Hz, OH-3′), 5.44 (d, 1H, $J_{OH,2'}$ = 6.4 Hz, OH-2′), 6.16 (d, 1H, $J_{1',2'}$ = 6.3 Hz, H-1′), 7.21 (bd, 1H, $J_{5,6}$ = 3.9 Hz, H-5), 7.78 (dd, 1H, $J_{5,4}$ = 5.1 Hz, $J_{5,2}$ = 2.9 Hz, H-5-thienyl), 7.91 (dd, 1H, $J_{4,5}$ = 5.1 Hz, $J_{4,2}$ = 1.3 Hz, H-4-thienyl), 7.99 (d, 1H, $J_{6,5}$ = 3.9 Hz, H-6), 8.62 ppm (dd, 1H, $J_{2,5}$ = 2.9 Hz, $J_{2,4}$ = 1.3 Hz, H-2-thienyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 61.7 (CH_2-5′), 70.8 (CH-3′), 74.3 (CH-2′), 85.6 (CH-4′), 86.7 (C-1′), 101.8 (CH-5), 113.7 (C-4a), 127.5 (CH-4-thienyl), 127.9 (CH-5-thienyl), 128.8 (CH-6), 130.3 (CH-2-thienyl), 138.7 (C-3-thienyl), 152.5 (C-2), 153.5 (C-7a), 153.7 ppm (C-4); IR (ATR): $\tilde{\nu}$ = 3427, 3114, 2924, 2855, 1566, 1559, 1511, 1452, 1412, 1386, 1368, 1297, 1249, 1230, 1153, 1079, 1054, 898, 849, 818, 775, 740, 722, 686 cm^{-1}; MS (ESI) *m/z* (%): 368 (5) $[M+H]^+$, 390 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{14}O_4N_3ClNaS$ $[M+Na]^+$ calcd: 390.02858, found: 390.02870; Anal. calcd for $C_{15}H_{14}O_4N_3ClS\cdot0.5\,H_2O$: C 47.81, H 4.01, N 11.15, found: C 48.18, H 3.82, N 10.77.

2-Chloro-4-phenyl-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (7 e). Compound **18** (160 mg, 0.5 mmol) was reacted with phenylboronic acid (67 mg, 0.55 mmol) for 10 min according to general procedure B (only one-half quantities for catalysts) to give **7 e** as a colorless oil (72 mg, 40%) that was recrystallized from H_2O/MeOH 4:1 to provide a white solid: mp: 173–175 °C; $[\alpha]_D^{20}$ = −44.6 (*c* = 0.204, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 3.58 (ddd, 1H, J_{gem} = 12.0 Hz, $J_{5'a,OH}$ = 5.4 Hz, $J_{5'a,4'}$ = 3.9 Hz, H-5′a), 3.65 (ddd, 1H, J_{gem} = 12.0 Hz, $J_{5'b,OH}$ = 5.4 Hz, $J_{5'b,4'}$ = 4.2 Hz, H-5′b), 3.96 (btd, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.0 Hz, $J_{4',3'}$ = 3.0 Hz, H-4′), 4.13 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 5.0 Hz, $J_{3',4'}$ = 3.0 Hz, H-3′), 4.44 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.4 Hz, $J_{2',3'}$ = 5.0 Hz, H-2′), 5.07 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.4 Hz, OH-5′), 5.26 (d, 1H, $J_{OH,3'}$ = 4.9 Hz, OH-3′), 5.45 (d, 1H, $J_{OH,2'}$ = 6.4 Hz, OH-2′), 6.19 (d, 1H, $J_{1',2'}$ = 6.4 Hz, H-1′), 7.08 (d, 1H, $J_{5,6}$ = 3.8 Hz, H-5), 7.60–7.64 (m, 3H, H-*p*,*m*-Ph), 8.01 (d, 1H, $J_{6,5}$ = 3.9 Hz, H-6), 8.15 ppm (m, 2H, H-*o*-Ph); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 61.7 (CH_2-5′), 70.8 (CH-3′), 74.3 (CH-2′), 85.7 (CH-4′), 86.8 (CH-1′), 101.8 (CH-5), 114.7 (C-4a), 129.0 (CH-*o*-Ph), 129.0 (CH-6), 129.3 (CH-*m*-Ph), 131.3 (CH-*p*-Ph), 136.3 (C-*i*-Ph), 152.6 (C-2), 153.7 (C-7a), 158.4 ppm (C-4); IR (ATR): $\tilde{\nu}$ = 3418, 3066, 1602, 1585, 1561, 1514, 1498, 1460, 1437, 1268, 1236, 1111, 1087, 1078, 1053, 1041, 1029, 1002, 894, 877, 842, 734, 696, 603 cm^{-1}; MS (ESI) *m/z* (%): 362 (10) $[M+H]^+$, 384 (100) $[M+Na]^+$; HRMS (ESI) for $C_{17}H_{16}O_4N_3ClNa$ $[M+Na]^+$ calcd: 384.07215, found: 384.07227; Anal. calcd for $C_{17}H_{16}O_4N_3Cl$: C 56.44, H 4.46, N 11.61, found: C 56.15, H 4.26, N 11.47.

2-Chloro-4-(benzofuran-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo-[2,3-*d*]pyrimidine (7 f). Compound **18** (160 mg, 0.5 mmol) was reacted with 2-benzofurylboronic acid (89 mg, 0.55 mmol) for 10 min according to general procedure B (only one-half quantities for catalysts) to give **7 f** as a light-yellow oil (176 mg, 88%) that was recrystallized from H_2O/MeOH 4:1 to provide a pale-yellow solid: mp: 226–230 °C; $[\alpha]_D^{20}$ = −55.5 (*c* = 0.218, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): δ = 3.59 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 5.4 Hz, $J_{5'a,4'}$ = 4.0 Hz, H-5′a), 3.67 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.4 Hz, $J_{5'b,4'}$ = 4.0 Hz, H-5′b), 3.96 (btd, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.0 Hz, $J_{4',3'}$ = 3.2 Hz, H-4′), 4.14 (td, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 5.0 Hz, $J_{3',4'}$ = 3.1 Hz, H-3′), 4.45 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.3 Hz, $J_{2',3'}$ = 5.1 Hz, H-2′), 5.08 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.4 Hz, OH-5′), 5.26 (d, 1H, $J_{OH,3'}$ = 5.0 Hz, OH-3′), 5.47 (d, 1H, $J_{OH,2'}$ = 6.4 Hz, OH-2′), 6.18 (d, 1H, $J_{1',2'}$ = 6.3 Hz, H-1′), 7.32 (bd, 1H, $J_{5,6}$ = 3.8 Hz, H-5), 7.38 (m, 1H, H-5-benzofuryl), 7.51 (m, 1H, H-6-benzofuryl), 7.81–7.85 (m, 2H, H-4,7-benzofuryl), 8.00 (d, 1H, $J_{3,7}$ = 0.9 Hz, H-3-benzofuryl), 8.07 ppm (d, 1H, $J_{6,5}$ = 3.8 Hz, H-6); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): δ = 61.7 (CH_2-5′), 70.8 (CH-3′), 74.3 (CH-2′), 85.7 (CH-4′), 86.8 (CH-1′), 102.2 (CH-5), 110.9 (CH-3-benzofuryl), 112.2 (CH-7-benzofuryl), 113.2 (C-4a), 122.9 (CH-4-benzofuryl), 124.2 (CH-5-benzofuryl), 127.3 (CH-6-benzofuryl), 127.8 (C-3a-benzofuryl), 129.6 (CH-6), 148.1 (C-4), 152.5 and 152.7 (C-2, C-2-benzofuryl), 154.0 (C-7a), 155.6 ppm (C-7a-benzofuryl); IR (ATR): $\tilde{\nu}$ = 3410, 1598, 1562, 1548, 1510, 1452, 1444, 1285, 1257, 1246, 1128, 1080, 1042, 987, 895, 890, 742 cm^{-1}; MS (ESI) *m/z* (%): 402 (15) $[M+H]^+$, 424 (100) $[M+Na]^+$; HRMS (ESI) for $C_{19}H_{16}O_5N_3ClNa$ $[M+Na]^+$ calcd: 424.06707, found: 424.06706; Anal. calcd for $C_{19}H_{16}O_5N_3Cl\cdot0.5\,H_2O$: C 55.55, H 4.17, N 10.23, found: C 55.94, H 4.06, N 9.80.

2-Chloro-4-(dibenzofuran-4-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo-[2,3-*d*]pyrimidine (7 g). Compound **18** (160 mg, 0.5 mmol) was reacted with 4-dibenzofurylboronic acid (117 mg, 0.55 mmol) for 10 min according to general procedure B (only one-half quantities for catalysts) to give **7 g** as a light-yellow solid (145 mg, 64%) that was recrystallized from H_2O/MeOH 4:1 to provide a beige solid: mp: 232–237 °C; $[\alpha]_D^{20}$ = −25.8 (*c* = 0.225, DMSO); ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): δ = 3.59 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'a,OH}$ = 5.3 Hz, $J_{5'a,4'}$ = 3.9 Hz, H-5′a), 3.66 (ddd, 1H, J_{gem} = 11.9 Hz, $J_{5'b,OH}$ = 5.4 Hz, $J_{5'b,4'}$ = 4.2 Hz, H-5′b), 3.98 (td, 1H, $J_{4',5'a}$ = $J_{4',5'b}$ = 4.0 Hz, $J_{4',3'}$ = 2.9 Hz, H-4′), 4.15 (btd, 1H, $J_{3',2'}$ = $J_{3',OH}$ = 4.9 Hz, $J_{3',4'}$ = 2.9 Hz, H-3′), 4.49 (td, 1H, $J_{2',1'}$ = $J_{2',OH}$ = 6.5 Hz, $J_{2',3'}$ = 5.0 Hz, H-2′), 5.07 (t, 1H, $J_{OH,5'a}$ = $J_{OH,5'b}$ = 5.4 Hz, OH-5′), 5.27 (d, 1H, $J_{OH,3'}$ = 4.9 Hz, OH-3′), 5.48 (d, 1H, $J_{OH,2'}$ = 6.5 Hz, OH-2′), 6.24 (d, 1H, $J_{1',2'}$ = 6.5 Hz, H-1′), 6.82 (dd, 1H, $J_{5,6}$ = 3.8 Hz; $J_{5,LR}$ = 0.5 Hz; H-5), 7.47 (ddd, 1H, $J_{8,9}$ = 7.7 Hz, $J_{8,7}$ = 7.3 Hz, $J_{8,6}$ = 0.9 Hz, H-8-$C_{12}H_7O$), 7.57 (ddd, 1H, $J_{7,6}$ = 8.3 Hz, $J_{7,8}$ = 7.3 Hz, $J_{7,9}$ = 1.4 Hz, H-7-$C_{12}H_7O$), 7.63 (t, 1H, $J_{2,1}$ = $J_{2,3}$ = 7.7 Hz, H-2-$C_{12}H_7O$), 7.73 (dt, 1H, $J_{6,7}$ = 8.2 Hz, $J_{6,8}$ = $J_{6,9}$ = 0.8 Hz, H-6-$C_{12}H_7O$), 7.98 (dd, 1H, $J_{3,2}$ = 7.6 Hz, $J_{3,1}$ = 1.3 Hz, H-3-$C_{12}H_7O$), 8.01 (d, 1H, $J_{6,5}$ = 3.8 Hz, H-6), 8.26 (ddd, 1H, $J_{9,8}$ = 7.7 Hz, $J_{9,7}$ = 1.4 Hz, $J_{9,6}$ = 0.7 Hz, H-9-$C_{12}H_7O$), 8.40 ppm (dd, 1H, $J_{1,2}$ = 7.7 Hz, $J_{1,3}$ = 1.3 Hz, H-1-$C_{12}H_7O$); ^{13}C NMR (150.9 MHz, [D$_6$]DMSO): δ = 61.7 (CH_2-5′), 70.9 (CH-3′), 74.3 (CH-2′), 85.8 (CH-4′), 86.7 (C-1′), 102.6 (CH-5), 112.1 (CH-6-$C_{12}H_7O$), 116.7 (C-4a), 121.2 (C-4-$C_{12}H_7O$), 121.6 (CH-9-$C_{12}H_7O$), 123.3 (C-9a-$C_{12}H_7O$), 123.8 (CH-1,2,8-$C_{12}H_7O$), 125.1 (C-9b-$C_{12}H_7O$), 128.3 (CH-7-$C_{12}H_7O$), 128.7 (CH-6), 128.8 (CH-3-$C_{12}H_7O$), 152.6 (C-2), 152.8 (C-4a-$C_{12}H_7O$), 153.3 (C-7a), 155.7 and 155.7 ppm (C-4, C-5a-$C_{12}H_7O$); IR (ATR): $\tilde{\nu}$ = 3421, 3116, 1604, 1586, 1562, 1507, 1493, 1454, 1410, 1298, 1243, 1191, 1168, 1154, 1111, 1077, 1057, 845, 747, 735, 602 cm^{-1}; MS (ESI) *m/z* (%): 452 (5) $[M+H]^+$, 474 (100) $[M+Na]^+$; HRMS (ESI) for $C_{23}H_{18}O_5N_3ClNa$ $[M+Na]^+$ calcd:

474.08272, found: 474.08278; Anal. calcd for $C_{23}H_{18}O_5N_3Cl$: C 61.14, H 4.02, N 9.30, found: C 61.35, H 4.37, N 8.96.

2-Fluoro-4-(furan-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (8a). Compound **19** (152 mg, 0.5 mmol) was reacted with 2-furylboronic acid (84 mg, 0.75 mmol) for 30 min according to general procedure B to give **8a** as a pale-yellow oil (156 mg, 93%) that was lyophilized to provide a brown solid: mp: 135–141 °C; $[\alpha]_D^{20} = -60.6$ ($c = 0.254$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.57$ (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.4$ Hz, $J_{5'a,4'} = 3.9$ Hz, H-5′a), 3.65 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.1$ Hz, H-5′b), 3.94 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 4.0$ Hz, $J_{4',3'} = 3.2$ Hz, H-4′), 4.11 (td, 1H, $J_{3',2'} = J_{3',OH} = 5.0$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.40 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.06 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.4$ Hz, OH-5′), 5.23 (d, 1H, $J_{OH,3'} = 4.9$ Hz, OH-3′), 5.43 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.10 (d, 1H, $J_{1',2'} = 6.2$ Hz, H-1′), 6.83 (dd, 1H, $J_{4,3} = 3.6$ Hz, $J_{4,5} = 1.7$ Hz, H-4-furyl), 7.11 (dd, 1H, $J_{5,6} = 3.8$ Hz, $J_{5,LR} = 0.5$ Hz, H-5), 7.55 (dd, 1H, $J_{3,4} = 3.6$ Hz, $J_{3,5} = 0.8$ Hz, H-3-furyl), 7.92 (d, 1H, $J_{6,5} = 3.8$ Hz, H-6), 8.11 ppm (dd, 1H, $J_{5,4} = 1.7$ Hz, $J_{5,3} = 0.8$ Hz, H-5-furyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 61.7$ (CH_2-5′), 70.7 (CH-3′), 74.3 (CH-2′), 85.6 (CH-4′), 86.8 (C-1′), 102.2 (CH-5), 111.5 (d, $J_{C,F} = 3.4$ Hz, C-4a), 113.3 (CH-4-furyl), 115.3 (CH-3-furyl), 128.6 (d, $J_{C,F} = 3.3$ Hz, CH-6), 147.5 (CH-5-furyl), 148.4 (d, $J_{C,F} = 16.1$ Hz, C-4), 151.4 (C-2-furyl), 154.5 (d, $J_{C,F} = 16.3$ Hz, C-7a), 158.5 ppm (d, $J_{C,F} = 205.4$ Hz, C-2); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): $\delta = -50.34$ ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu} = 3155$, 1605, 1578, 1518, 1489, 1393, 1296, 1250, 1193, 1156, 1120, 1020, 987, 896, 886, 595 cm^{-1}; MS (ESI) *m/z* (%): 336 (10) $[M+H]^+$, 358 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{14}O_5N_3FNa$ $[M+Na]^+$ calcd: 358.08097, found: 358.08088; Anal. calcd for $C_{15}H_{14}O_5N_3F{\cdot}1.65\,H_2O$: C 49.36, H 4.78, N 11.51, found: C 49.81, H 4.35, N 10.99.

2-Fluoro-4-(thien-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (8b). Compound **19** (152 mg, 0.5 mmol) was reacted with 2-thienylboronic acid (96 mg, 0.75 mmol) for 1 h according to general procedure B to give **8b** as a pale-brown oil (172 mg, 98%) that was recrystallized from H_2O/MeOH 4:1 to provide a yellow solid: mp: 124–130 °C; $[\alpha]_D^{20} = -61.5$ ($c = 0.213$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.57$ (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.3$ Hz, $J_{5'a,4'} = 3.9$ Hz, H-5′a), 3.65 (bddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.5$ Hz, $J_{5'b,4'} = 4.0$ Hz, H-5′b), 3.94 (m, 1H, H-4′), 4.12 (td, 1H, $J_{3',2'} = J_{3',OH} = 5.1$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.40 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.2$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.07 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.4$ Hz, OH-5′), 5.23 (d, 1H, $J_{OH,3'} = 5.0$ Hz, OH-3′), 5.44 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.10 (d, 1H, $J_{1',2'} = 6.1$ Hz, H-1′), 7.24 (bd, 1H, $J_{5,6} = 3.8$ Hz, H-5), 7.34 (dd, 1H, $J_{4,5} = 5.0$ Hz, $J_{4,3} = 3.8$ Hz, H-4-thienyl), 7.96 (d, 1H, $J_{6,5} = 3.8$ Hz, H-6), 7.96 (dd, 1H, $J_{5,4} = 5.0$ Hz, $J_{5,3} = 1.1$ Hz, H-5-thienyl), 8.25 ppm (dd, 1H, $J_{3,4} = 3.9$ Hz, $J_{3,5} = 1.1$ Hz, H-3-thienyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 61.6$ (CH_2-5′), 70.7 (CH-3′), 74.3 (CH-2′), 85.6 (CH-4′), 86.9 (C-1′), 101.8 (CH-5), 111.9 (d, $J_{C,F} = 3.7$ Hz, C-4a), 128.8 (d, $J_{C,F} = 3.4$ Hz, CH-6), 129.6 (CH-4-thienyl), 131.2 (CH-3-thienyl), 132.3 (CH-5-thienyl), 140.8 (C-2-thienyl), 152.6 (d, $J_{C,F} = 15.3$ Hz, C-4), 154.4 (d, $J_{C,F} = 16.2$ Hz, C-7a), 158.1 ppm (d, $J_{C,F} = 206.2$ Hz, C-2); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): $\delta = -50.76$ ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu} =$ 3146, 3119, 1578, 1571, 1261, 1204 cm^{-1}; MS (ESI) *m/z* (%): 352 (5) $[M+H]^+$, 374 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{14}O_4N_3FNaS$ $[M+Na]^+$ calcd: 374.05813, found: 374.05809; Anal. calcd for $C_{15}H_{14}O_4N_3FS{\cdot}1.35\,H_2O$: C 47.96, H 4.48, N 11.19, found: C 48.08, H 4.18, N 10.89.

2-Fluoro-4-(furan-3-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (8c). Compound **19** (152 mg, 0.5 mmol) was reacted with 3-furylboronic acid (84 mg, 0.75 mmol) for 30 min according to general procedure B to afford **8c** as a pale-yellow oil (154 mg, 92%) that was lyophilized to provide a beige solid: mp: 136–141 °C; $[\alpha]_D^{20} = -49.2$ ($c = 0.189$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.57$ (bddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.3$ Hz, $J_{5'a,4'} = 4.0$ Hz, H-5′a), 3.65 (bddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.3$ Hz, $J_{5'b,4'} = 4.1$ Hz, H-5′b), 3.94 (btd, 1H, $J_{4',5'a} = J_{4',5'b} = 4.0$ Hz, $J_{4',3'} = 3.3$ Hz, H-4′), 4.12 (td, 1H, $J_{3',2'} = J_{3',OH} = 4.9$ Hz, $J_{3',4'} = 3.3$ Hz, H-3′), 4.40 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.2$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.06 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.3$ Hz, OH-5′), 5.22 (d, 1H, $J_{OH,3'} = 5.0$ Hz, OH-3′), 5.43 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.10 (d, 1H, $J_{1',2'} = 6.1$ Hz, H-1′), 7.17 (bd, 1H, $J_{5,6} = 3.9$ Hz, H-5), 7.24 (dd, 1H, $J_{4,5} = 1.9$ Hz, $J_{4,2} = 0.9$ Hz, H-4-furyl), 7.92 (d, 1H, $J_{6,5} = 3.9$ Hz, H-6), 7.93 (bt, 1H, $J_{5,4} = J_{5,2} = 1.7$ Hz, H-5-furyl), 8.81 ppm (dd, 1H, $J_{2,5} = 1.5$ Hz, $J_{2,4} = 0.9$ Hz, H-2-furyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 61.6$ (CH_2-5′), 70.7 (CH-3′), 74.3 (CH-2′), 85.5 (CH-4′), 86.9 (C-1′), 101.7 (CH-5), 109.4 (CH-4-furyl), 113.3 (d, $J_{C,F} = 3.7$ Hz, C-4a), 124.3 (C-3-furyl), 128.2 (d, $J_{C,F} = 3.4$ Hz, CH-6), 145.2 (CH-5-furyl), 146.2 (CH-2-furyl), 152.8 (d, $J_{C,F} = 15.6$ Hz, C-4), 153.9 (d, $J_{C,F} = 16.3$ Hz, C-7a), 158.5 ppm (d, $J_{C,F} = 205.6$ Hz, C-2); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): $\delta = -50.43$ ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu} = 3428$, 3155, 1599, 1584, 1564, 1515, 1467, 1390, 1373, 1355, 1294, 1237, 1194, 1163, 1118, 1082, 1050, 1021, 986, 897, 873, 597 cm^{-1}; MS (ESI) *m/z* (%): 336 (10) $[M+H]^+$, 358 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{14}O_5N_3FNa$ $[M+Na]^+$ calcd: 358.08097, found: 358.08092; Anal. calcd for $C_{15}H_{14}O_5N_3F{\cdot}1\,H_2O$: C 50.99, H 4.56, N 11.89, found: C 50.70, H 4.17, N 11.62.

2-Fluoro-4-(thien-3-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]-pyrimidine (8d). Compound **19** (152 mg, 0.5 mmol) was reacted with 3-thienylboronic acid (96 mg, 0.75 mmol) for 30 min according to general procedure B to give **8d** as a light-yellow oil (141 mg, 80%) that was recrystallized from H_2O/MeOH 4:1 to provide a beige solid: mp: 83–87 °C; $[\alpha]_D^{20} = -61.6$ ($c = 0.294$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.57$ (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'a,OH} = 5.5$ Hz, $J_{5'a,4'} = 4.0$ Hz, H-5′a), 3.65 (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.0$ Hz, H-5′b), 3.94 (bq, 1H, $J_{4',5'a} = J_{4',5'b} = J_{4',3'} = 3.6$ Hz, H-4′), 4.12 (td, 1H, $J_{3',2'} = J_{3',OH} = 5.0$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.41 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.07 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.4$ Hz, OH-5′), 5.23 (d, 1H, $J_{OH,3'} = 4.9$ Hz, OH-3′), 5.43 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.12 (d, 1H, $J_{1',2'} = 6.2$ Hz, H-1′), 7.21 (d, 1H, $J_{5,6} = 3.9$ Hz, H-5), 7.78 (dd, 1H, $J_{5,4} = 5.1$ Hz, $J_{5,2} = 2.9$ Hz, H-5-thienyl), 7.93 (dd, 1H, $J_{4,5} = 5.1$ Hz, $J_{4,2} = 1.3$ Hz, H-4-thienyl), 7.95 (d, 1H, $J_{6,5} = 3.9$ Hz, H-6), 8.64 ppm (dd, 1H, $J_{2,5} = 2.9$ Hz, $J_{2,4} = 1.3$ Hz, H-2-thienyl); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 61.6$ (CH_2-5′), 70.7 (CH-3′), 74.3 (CH-2′), 85.6 (CH-4′), 86.9 (C-1′), 102.0 (CH-5), 113.3 (d, $J_{C,F} = 3.6$ Hz, C-4a), 127.5 (CH-5-thienyl), 127.9 (CH-4-thienyl), 128.5 (d, $J_{C,F} = 3.3$ Hz, CH-6), 130.4 (CH-2-thienyl), 138.7 (C-3-thienyl), 154.0 (d, $J_{C,F} = 15.1$ Hz, C-4), 154.4 (d, $J_{C,F} = 16.1$ Hz, C-7a), 158.5 ppm (d, $J_{C,F} = 205.3$ Hz, C-2); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): $\delta = -50.33$ ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu} = 3146$, 3117, 1581, 1518, 1262 cm^{-1}; MS (ESI) *m/z* (%): 352 (10) $[M+H]^+$, 374 (100) $[M+Na]^+$; HRMS (ESI) for $C_{15}H_{14}O_4N_3FNaS$ $[M+Na]^+$ calcd: 374.05813, found: 374.05810; Anal. calcd for $C_{15}H_{14}O_4N_3FS{\cdot}1.2\,H_2O$: C 48.30, H 4.43, N 11.27, found: C 48.55, H 4.19, N 11.02.

2-Fluoro-4-phenyl-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (8e). Compound **19** (152 mg, 0.5 mmol) was reacted with phenylboronic acid (91 mg, 0.75 mmol) for 10 min according to general procedure B to give **8e** as a light-yellow oil (146 mg, 84%) that was recrystallized from H_2O/MeOH 4:1 to provide a beige solid: mp: 131–135 °C; $[\alpha]_D^{20} = -54.6$ ($c = 0.269$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 3.58$ (bddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'a,OH} = 5.3$ Hz, $J_{5'a,4'} = 4.1$ Hz, H-5′a), 3.65 (bddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.3$ Hz, H-5′b), 3.95 (m, 1H, H-4′), 4.13 (btd, 1H, $J_{3',2'} = J_{3',OH} = 5.1$ Hz, $J_{3',4'} = 3.2$ Hz, H-3′), 4.43 (btd, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.07 (bt, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.4$ Hz, OH-5′), 5.24 (d, 1H, $J_{OH,3'} = 5.0$ Hz, OH-3′), 5.45 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.15

(d, 1H, $J_{1',2'}=6.2$ Hz, H-1′), 7.09 (d, 1H, $J_{5,6}=3.9$ Hz, H-5), 7.60–7.64 (m, 3H, H-*p*,*m*-Ph), 7.97 (d, 1H, $J_{6,5}=3.9$ Hz, H-6), 8.17 ppm (m, 2H, H-*o*-Ph); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta=61.7$ (CH_2-5′), 70.8 (CH-3′), 74.3 (CH-2′), 85.6 (CH-4′), 86.9 (C-1′), 102.1 (CH-5), 114.4 (d, $J_{C,F}=3.7$ Hz, C-4a), 128.8 (d, $J_{C,F}=3.3$ Hz, CH-6), 129.0 (CH-*o*-Ph), 129.3 (CH-*m*-Ph), 131.3 (CH-*p*-Ph), 136.3 (C-*i*-Ph), 154.3 (d, $J_{C,F}=15.9$ Hz, C-7a), 158.6 (d, $J_{C,F}=205.8$ Hz, C-2), 159.0 ppm (d, $J_{C,F}=14.6$ Hz, C-4); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): $\delta=-50.24$ ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu}=3118$, 1592, 1579, 1521, 1499, 1443, 1265, 1205, 699 cm^{-1}; MS (ESI) *m/z* (%): 346 (10) $[M+H]^+$, 368 (100) $[M+Na]^+$; HRMS (ESI) for $C_{17}H_{17}O_4N_3F$ $[M+H]^+$ calcd: 346.11976, found: 346.11970; Anal. calcd for $C_{17}H_{16}O_4N_3F\cdot1.1\,H_2O$: C 55.92, H 5.02, N 11.51, found: C 56.37, H 4.78, N 10.99.

2-Fluoro-4-(benzofuran-2-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo-[2,3-*d*]pyrimidine (8 f). Compound **19** (152 mg, 0.5 mmol) was reacted with 2-benzofurylboronic acid (121 mg, 0.75 mmol) for 1 h according to general procedure B to give **8 f** as a yellow solid (187 mg, 97%) that was recrystallized from H_2O/MeOH 4:1 to provide a yellow solid: mp: 188–192 °C; $[\alpha]_D^{20}=-75.5$ ($c=0.269$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta=3.59$ (ddd, 1H, $J_{gem}=11.9$ Hz, $J_{5'a,OH}=5.4$ Hz, $J_{5'a,4'}=4.0$ Hz, H-5′a), 3.67 (ddd, 1H, $J_{gem}=11.8$ Hz, $J_{5'b,OH}=5.4$ Hz, $J_{5'b,4'}=4.0$ Hz, H-5′b), 3.96 (btd, 1H, $J_{4',5'a}=J_{4',5'b}=4.0$ Hz, $J_{4',3'}=3.3$ Hz, H-4′), 4.14 (td, 1H, $J_{3',2'}=J_{3',OH}=5.0$ Hz, $J_{3',4'}=3.3$ Hz, H-3′), 4.43 (td, 1H, $J_{2',1'}=J_{2',OH}=6.2$ Hz, $J_{2',3'}=5.1$ Hz, H-2′), 5.08 (t, 1H, $J_{OH,5'a}=J_{OH,5'b}=5.4$ Hz, OH-5′), 5.25 (d, 1H, $J_{OH,3'}=5.0$ Hz, OH-3′), 5.46 (d, 1H, $J_{OH,2'}=6.4$ Hz, OH-2′), 6.14 (d, 1H, $J_{1',2'}=6.1$ Hz, H-1′), 7.33 (bd, 1H, $J_{5,6}=3.8$ Hz, H-5), 7.38 (ddd, 1H, $J_{5,4}=7.9$ Hz, $J_{5,6}=7.2$ Hz, $J_{5,7}=0.9$ Hz, H-5-benzofuryl), 7.52 (ddd, 1H, $J_{6,7}=8.3$ Hz, $J_{6,5}=7.2$ Hz, $J_{6,4}=1.3$ Hz, H-6-benzofuryl), 7.81–7.85 (m, 2H, H-4,7-benzofuryl), 8.01 (d, 1H, $J_{3,7}=1.0$ Hz, H-3-benzofuryl), 8.03 ppm (d, 1H, $J_{6,5}=3.8$ Hz, H-6); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta=61.6$ (CH_2-5′), 70.7 (CH-3′), 74.3 (CH-2′), 85.6 (CH-4′), 86.9 (C-1′), 102.4 (CH-5), 110.9 (CH-3-benzofuryl), 112.2 (CH-7-benzofuryl), 113.0 (d, $J_{C,F}=3.4$ Hz, C-4a), 122.9 (CH-4-benzofuryl), 124.2 (CH-5-benzofuryl), 127.4 (CH-6-benzofuryl), 127.8 (C-3a-benzofuryl), 129.3 (d, $J_{C,F}=3.4$ Hz, CH-6), 148.3 (d, $J_{C,F}=15.8$ Hz, C-4), 152.8 (C-2-benzofuryl), 154.8 (d, $J_{C,F}=16.2$ Hz, C-7a), 155.7 (C-7a-benzofuryl), 158.5 ppm (d, $J_{C,F}=205.9$ Hz, C-2); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): $\delta=-50.28$ ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu}=3121$, 1602, 1581, 1560, 1519, 1450, 1265, 1253, 1051 cm^{-1}; MS (ESI) *m/z* (%): 408 (100) $[M+Na]^+$; HRMS (ESI) for $C_{19}H_{16}O_5N_3FNa$ $[M+Na]^+$ calcd: 408.09662, found: 408.09664; Anal. calcd for $C_{19}H_{16}O_5N_3F\cdot0.7\,H_2O$: C 57.34, H 4.41, N 10.56, found: C 57.74, H 4.35, N 10.10.

2-Fluoro-4-(dibenzofuran-4-yl)-7-(β-D-ribofuranosyl)-7*H*-pyrrolo-[2,3-*d*]pyrimidine (8 g). Compound **19** (152 mg, 0.5 mmol) was reacted with 4-dibenzofurylboronic acid (159 mg, 0.75 mmol) for 30 min according to general procedure B to give **8 g** as a yellow oil (145 mg, 67%) that was recrystallized from H_2O/MeOH 4:1 to provide a white solid: mp: 196–201 °C; $[\alpha]_D^{20}=-39.9$ ($c=0.218$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta=3.59$ (bddd, 1H, $J_{gem}=11.9$ Hz, $J_{5'a,OH}=5.4$ Hz, $J_{5'a,4'}=4.0$ Hz, H-5′a), 3.66 (bddd, 1H, $J_{gem}=11.8$ Hz, $J_{5'b,OH}=5.4$ Hz, $J_{5'b,4'}=4.2$ Hz, H-5′b), 3.98 (m, 1H, H-4′), 4.15 (td, 1H, $J_{3',2'}=J_{3',OH}=5.0$ Hz, $J_{3',4'}=3.1$ Hz, H-3′), 4.47 (td, 1H, $J_{2',1'}=J_{2',OH}=6.4$ Hz, $J_{2',3'}=5.0$ Hz, H-2′), 5.08 (t, 1H, $J_{OH,5'a}=J_{OH,5'b}=5.4$ Hz, OH-5′), 5.26 (d, 1H, $J_{OH,3'}=4.9$ Hz, OH-3′), 5.49 (d, 1H, $J_{OH,2'}=6.5$ Hz, OH-2′), 6.20 (d, 1H, $J_{1',2'}=6.4$ Hz, H-1′), 6.85 (bd, 1H, $J_{5,6}=3.8$ Hz, H-5), 7.48 (bddd, 1H, $J_{8,9}=7.6$ Hz, $J_{8,7}=7.4$ Hz, $J_{8,6}=1.0$ Hz, H-8-$C_{12}H_7O$), 7.57 (ddd, 1H, $J_{7,6}=8.3$ Hz, $J_{7,8}=7.3$ Hz, $J_{7,9}=1.4$ Hz, H-7-$C_{12}H_7O$), 7.63 (t, 1H, $J_{2,1}=J_{2,3}=7.7$ Hz, H-2-$C_{12}H_7O$), 7.74 (dt, 1H, $J_{6,7}=8.2$ Hz, $J_{6,8}=J_{6,9}=0.8$ Hz, H-6-$C_{12}H_7O$), 7.97 (d, 1H, $J_{6,5}=3.8$ Hz, H-6), 8.00 (dd, 1H, $J_{3,2}=7.6$ Hz, $J_{3,1}=1.3$ Hz, H-3-$C_{12}H_7O$), 8.27 (ddd, 1H, $J_{9,8}=7.7$ Hz, $J_{9,7}=1.3$ Hz, $J_{9,6}=0.6$ Hz, H-9-$C_{12}H_7O$), 8.41 ppm (dd, 1H, $J_{1,2}=7.7$ Hz, $J_{1,3}=1.3$ Hz, H-1-$C_{12}H_7O$); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta=61.7$ (CH_2-5′), 70.9 (CH-3′), 74.3 (CH-2′), 85.7 (CH-4′), 86.9 (C-1′), 102.8 (CH-5), 112.1 (CH-6-$C_{12}H_7O$), 116.3 (d, $J_{C,F}=3.7$ Hz, C-4a), 121.3 (C-4-$C_{12}H_7O$), 121.6 (CH-9-$C_{12}H_7O$), 123.3 (C-9a-$C_{12}H_7O$), 123.8 (CH-2,8-$C_{12}H_7O$), 123.9 (CH-1-$C_{12}H_7O$), 125.2 (C-9b-$C_{12}H_7O$), 128.4 (CH-7-$C_{12}H_7O$), 128.4 (d, $J_{C,F}=3.4$ Hz, CH-6), 128.8 (CH-3-$C_{12}H_7O$), 152.8 (C-4a-$C_{12}H_7O$), 154.0 (d, $J_{C,F}=16.1$ Hz, C-7a), 155.7 (C-5a-$C_{12}H_7O$), 156.2 (d, $J_{C,F}=15.1$ Hz, C-4), 158.6 ppm (d, $J_{C,F}=206.5$ Hz, C-2); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): $\delta=-50.14$ ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu}=1578$, 1518, 1452, 1249, 1190 cm^{-1}; MS (ESI) *m/z* (%):436 (10) $[M+H]^+$, 458 (100) $[M+Na]^+$; HRMS (ESI) for $C_{23}H_{19}O_5N_3F$ $[M+H]^+$ calcd: 436.13033, found: 436.13042; Anal. calcd for $C_{23}H_{18}O_5N_3F\cdot0.8\,H_2O$: C 61.41, H 4.39, N 9.34, found: C 61.89, H 4.30, N 8.78.

2-Trifluoroacetamido-4-chloro-7-(2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (20). To a solution of compound **12** (2.69 g, 5.9 mmol) in CH_2Cl_2 (50 mL) was added Hunig's base (3.1 mL, 17.7 mmol) at room temperature, followed by trifluoroacetic anhydride (1.64 mL, 11.8 mmol). After 2 h of stirring at room temperature, aqueous NH_4Cl (sat, 50 mL) was added and the mixture extracted with CH_2Cl_2 (2×50 mL). The combined organic extracts were dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica (hexanes/EtOAc, 10:1) to afford **20** (2.415 g, 70%) as a yellow oil: ^{1}H NMR (400 MHz, [D$_6$]DMSO): $\delta=-0.14$ and -0.11 (2s, 2×3H, CH_3Si), 0.76 (s, 9H, $(CH_3)_3C$), 1.34 and 1.53 (2s, 2×3H, $(CH_3)_2C$), 3.63 (d, 2H, $J_{gem}=11.2$ Hz, 2H-5′), 4.13 (td, 1H, $J_{4',5'a}=J_{4',5'b}=5.2$ Hz, $J_{4',3'}=3.4$ Hz, H-4′), 5.15 (dd, 1H, $J_{3',2'}=6.3$ Hz, $J_{3',4'}=3.4$ Hz, H-3′), 5.52 (dd, 1H, $J_{2',3'}=6.3$ Hz, $J_{2',1'}=2.7$ Hz, H-2′), 6.27 (d, 1H, $J_{1',2'}=2.7$ Hz, H-1′), 6.74 (d, 1H, $J_{5,6}=3.8$ Hz, H-5), 7.86 (d, 1H, $J_{6,5}=3.8$ Hz, H-6), 12.43 ppm (s, 1H, NH-2); ^{19}F NMR (313.5 MHz, [D$_6$]DMSO): $\delta=-70.39$ ppm (s, 3F, CF_3); MS (ESI) *m/z* (%): 551 (20) $[M+H]^+$, 573 (100) $[M+Na]^+$; HRMS (ESI) for $C_{22}H_{30}O_5N_4ClF_3NaSi$ $[M+Na]^+$ calcd: 573.15183, found: 573.15174.

2-Trifluoroacetamido-4-methyl-7-(2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (21). To an argon-purged solution of compound **20** (2.39 g, 4.34 mmol) in freshly distilled THF (50 mL) was added $Pd(PPh_3)_4$ (250 mg, 0.217 mmol) at room temperature, followed by $AlMe_3$ (2 M solution in toluene, 8.67 mL, 17.36 mmol) dropwise. The mixture was then heated at 75 °C. After stirring for 1.5 h and cooling, the mixture was diluted with EtOAc (100 mL) and $AlMe_3$ was neutralized with aqueous NH_4Cl (sat). The mixture was washed with H_2O (2×100 mL), the organic extract dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica (hexanes/EtOAc, 10:1) to afford **21** (1.583 g, 69%) as a light-yellow oil: ^{1}H NMR (400 MHz, [D$_6$]DMSO): $\delta=-0.13$ and -0.10 (2s, 2×3H, CH_3Si), 0.77 (s, 9H, $(CH_3)_3C$), 1.34 and 1.53 (2s, 2×3H, $(CH_3)_2C$), 2.66 (s, 3H, CH_3-4), 3.63 (d, 2H, $J_{gem}=11.2$ Hz, 2H-5′), 4.10 (td, 1H, $J_{4',5'a}=J_{4',5'b}=5.2$ Hz, $J_{4',3'}=3.4$ Hz, H-4′), 5.14 (dd, 1H, $J_{3',2'}=6.3$ Hz, $J_{3',4'}=3.4$ Hz, H-3′), 5.49 (dd, 1H, $J_{2',3'}=6.3$ Hz, $J_{2',1'}=2.7$ Hz, H-2′), 6.24 (d, 1H, $J_{1',2'}=2.7$ Hz, H-1′), 6.79 (d, 1H, $J_{5,6}=3.8$ Hz, H-5), 7.68 (d, 1H, $J_{6,5}=3.8$ Hz, H-6), 12.07 ppm (s, 1H, NH-2); ^{19}F NMR (313.5 MHz, [D$_6$]DMSO): $\delta=-70.37$ ppm (s, 3F, CF_3); MS (ESI) *m/z* (%): 531 (15) $[M+H]^+$, 553 (60) $[M+Na]^+$; HRMS (ESI) for $C_{23}H_{33}O_5N_4FNaSi$ $[M+Na]^+$ calcd: 553.20645, found: 553.20631.

2-Amino-4-methyl-7-(2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (22). To a solution of compound **21** (1.583 g, 2.98 mmol) in MeOH (25 mL) was added MeONa (382 mg, 7.15 mmol) at room temperature. After 2 h of stirring, the mixture is evaporated and the residue subjected to chromatography on silica (hexanes/EtOAc, 1:1) to afford

22 (1.3 g, quantitative reaction) as a colorless oil: ^{1}H NMR (400 MHz, [D$_6$]DMSO): $\delta = -0.03$ (s, 6H, CH_3Si), 0.83 (s, 9H, $(CH_3)_3C$), 1.32 and 1.52 (2s, 2×3H, $(CH_3)_2C$), 2.41 (s, 3H, CH_3-4), 3.69 (dd, 1H, $J_{gem} = 11.2$ Hz, $J_{5'a,4'} = 5.5$ Hz, H-5′a), 3.71 (dd, 1H, $J_{gem} = 11.2$ Hz, $J_{5'b,4'} = 4.9$ Hz, H-5′b), 4.05 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 5.2$ Hz, $J_{4',3'} = 3.4$ Hz, H-4′), 4.94 (dd, 1H, $J_{3',2'} = 6.3$ Hz, $J_{3',4'} = 3.4$ Hz, H-3′), 5.13 (dd, 1H, $J_{2',3'} = 6.3$ Hz, $J_{2',1'} = 2.7$ Hz, H-2′), 6.13 (d, 1H, $J_{1',2'} = 2.7$ Hz, H-1′), 6.24 (s, 2H, NH_2), 6.45 (d, 1H, $J_{5,6} = 3.8$ Hz, H-5), 7.15 ppm (d, 1H, $J_{6,5} = 3.8$ Hz, H-6); MS (ESI) *m/z* (%): 435 (100) $[M+H]^+$, 457 (20) $[M+Na]^+$, 473 (5) $[M+K]$; HRMS (ESI) for $C_{21}H_{35}O_4N_4Si$ $[M+H]^+$ calcd: 435.24221, found: 435.24226.

2-Chloro-4-methyl-7-(2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (23). A solution of BTEA-NO_2 (2.211 g, 9.3 mmol) in dry CH_2Cl_2 (10 mL) was added dropwise to a stirred, argon-purged solution of AcCl (0.55 mL, 7.75 mmol) in dry CH_2Cl_2 (25 mL) at 0 °C. Then, a solution of compound **22** (547 mg, 1.26 mmol) in dry CH_2Cl_2 (5 mL) was added dropwise to the mixture at 0 °C. After 1 h of stirring at room temperature, aqueous $NaHCO_3$ (sat, 50 mL) was added and the mixture extracted with $CHCl_3$ (50 mL, then 2×20 mL). The combined organic extracts were dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica (hexanes/EtOAc, 10:1) to afford **23** (258 mg, 45%) as a yellow oil: ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): $\delta = -0.023$ and -0.021 (2s, 2×3H, CH_3Si), 0.82 (s, 9H, $(CH_3)_3C$), 1.33 and 1.55 (2s, 2×3H, $(CH_3)_2C$), 2.66 (s, 3H, CH_3-4), 3.70 (dd, 1H, $J_{gem} = 11.2$ Hz, $J_{5'a,4'} = 5.4$ Hz, H-5′a), 3.75 (dd, 1H, $J_{gem} = 11.2$ Hz, $J_{5'b,4'} = 4.9$ Hz, H-5′b), 4.17 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 5.1$ Hz, $J_{4',3'} = 3.3$ Hz, H-4′), 4.92 (dd, 1H, $J_{3',2'} = 6.3$ Hz, $J_{3',4'} = 3.3$ Hz, H-3′), 5.22 (dd, 1H, $J_{2',3'} = 6.3$ Hz, $J_{2',1'} = 2.8$ Hz, H-2′), 6.24 (d, 1H, $J_{1',2'} = 2.8$ Hz, H-1′), 6.85 (d, 1H, $J_{5,6} = 3.8$ Hz, H-5), 7.74 ppm (d, 1H, $J_{6,5} = 3.8$ Hz, H-6); MS (ESI) *m/z* (%): 454 (65) $[M+H]^+$, 476 (100) $[M+Na]^+$; HRMS (ESI) for $C_{21}H_{32}O_4N_3ClNaSi$ $[M+Na]^+$ calcd: 476.17428, found: 476.17414.

2,4-Dimethyl-7-(2,3-*O*-isopropylidene-5-*O*-*tert*-butyldimethylsilyl-β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (24). To an argon-purged solution of compound **13** (272 mg, 0.6 mmol) in freshly distilled THF (5 mL) was added $Pd(PPh_3)_4$ (35 mg, 0.03 mmol) at room temperature, followed by $AlMe_3$ (2 M solution in toluene, 0.6 mL, 1.2 mmol) dropwise. The mixture was then heated at 75 °C. After stirring for 1.5 h and cooling, the mixture was diluted with EtOAc (20 mL) and $AlMe_3$ was neutralized with aqueous NH_4Cl (sat). The mixture was washed with H_2O (2×20 mL), the organic extract dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica (hexanes/EtOAc, 1:1) to afford **24** (203 mg, 78%) as a yellow oil: ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): $\delta = -0.033$ and -0.030 (2s, 2×3H, CH_3Si), 0.83 (s, 9H, $(CH_3)_3C$), 1.32 and 1.54 (2s, 2×3H, $(CH_3)_2C$), 2.60 (s, 3H, CH_3-4), 2.61 (s, 3H, CH_3-2), 3.69 (dd, 1H, $J_{gem} = 11.1$ Hz, $J_{5'a,4'} = 5.4$ Hz, H-5′a), 3.73 (dd, 1H, $J_{gem} = 11.1$ Hz, $J_{5'b,4'} = 5.0$ Hz, H-5′b), 4.12 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 5.2$ Hz, $J_{4',3'} = 3.4$ Hz, H-4′), 4.95 (dd, 1H, $J_{3',2'} = 6.4$ Hz, $J_{3',4'} = 3.4$ Hz, H-3′), 5.24 (dd, 1H, $J_{2',3'} = 6.4$ Hz, $J_{2',1'} = 2.8$ Hz, H-2′), 6.30 (d, 1H, $J_{1',2'} = 2.8$ Hz, H-1′), 6.70 (d, 1H, $J_{5,6} = 3.7$ Hz, H-5), 7.58 ppm (d, 1H, $J_{6,5} = 3.7$ Hz, H-6); MS (ESI) *m/z* (%): 434 (100) $[M+H]^+$, 456 (15) $[M+Na]^+$; HRMS (ESI) for $C_{22}H_{36}O_4N_3Si$ $[M+H]^+$ calcd: 434.24696, found: 434.24692.

2-Amino-4-methyl-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (5h). Compound **22** (729 mg, 1.68 mmol) was treated according to general procedure A and the residue subjected to chromatography on silica ($CHCl_3$/MeOH, 10:1) to afford compound **5h** as a beige solid after recrystallization from H_2O/MeOH 4:1 (470 mg, quantitative reaction): mp: 100–105 °C; $[\alpha]_D^{20} = -37.8$ ($c = 0.230$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 2.41$ (s, 3H, CH_3), 3.50 (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'a,OH} = 5.7$ Hz, $J_{5'a,4'} = 4.2$ Hz, H-5′a), 3.58 (ddd, 1H, $J_{gem} = 11.8$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.2$ Hz, H-5′b), 3.83 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 4.2$ Hz, $J_{4',3'} = 3.3$ Hz, H-4′), 4.05 (td, 1H, $J_{3',2'} = J_{3',OH} = 4.9$ Hz, $J_{3',4'} = 3.3$ Hz, H-3′), 4.31 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 4.6$ Hz, H-2′), 5.02 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.5$ Hz, OH-5′), 5.07 (d, 1H, $J_{OH,3'} = 4.6$ Hz, OH-3′), 5.24 (d, 1H, $J_{OH,2'} = 6.3$ Hz, OH-2′), 5.99 (d, 1H, $J_{1',2'} = 6.4$ Hz, H-1′), 6.13 (bs, 2H, NH_2), 6.42 (dd, 1H, $J_{5,6} = 3.8$ Hz, $J_{5,LR} = 0.6$ Hz, H-5), 7.22 ppm (d, 1H, $J_{6,5} = 3.8$ Hz, H-6); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 21.2$ (CH_3), 61.9 (CH_2-5′), 70.8 (CH-3′), 73.6 (CH-2′), 84.8 (CH-4′), 86.0 (CH-1′), 100.5 (CH-5), 110.3 (C-4a), 121.7 (CH-6), 153.4 (C-7a), 159.9 and 159.9 ppm (C-2,4); IR (ATR): $\tilde{\nu} = 3470$, 3348, 3212, 3106, 2922, 2870, 1634, 1603, 1581, 1521, 1492, 1414, 1367, 1290, 896, 796, 742 cm^{-1}; MS (ESI) *m/z* (%): 281 (100) $[M+H]^+$, 303 (80) $[M+Na]^+$; HRMS (ESI) for $C_{12}H_{17}O_4N_4$ $[M+H]^+$ calcd: 281.12443, found: 281.12456; Anal. calcd for $C_{12}H_{16}O_4N_4 \cdot 1.05\,H_2O$: C 48.17, H 6.10, N 18.73, found: C 48.28, H 5.94, N 18.70.

2,4-Dimethyl-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (6h). Compound **24** (198 mg, 0.46 mmol) was treated according to general procedure A and the residue subjected to chromatography on silica ($CHCl_3$/MeOH, 10:1) to afford compound **6h** (115 mg, 90%) as a white solid after lyophilization: mp: 100–105 °C; $[\alpha]_D^{20} = -59.0$ ($c = 0.205$, DMSO); ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): $\delta = 2.60$ (2s, 2×3H, CH_3-2,4), 3.54 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 6.2$ Hz, $J_{5'a,4'} = 3.9$ Hz, H-5′a), 3.62 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.1$ Hz, $J_{5'b,4'} = 4.0$ Hz, H-5′b), 3.91 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 3.9$ Hz, $J_{4',3'} = 2.9$ Hz, H-4′), 4.10 (tdd, 1H, $J_{3',2'} = J_{3',OH} = 4.9$ Hz, $J_{3',4'} = 2.9$ Hz, $J_{3',1'} = 0.4$ Hz, H-3′), 4.44 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.5$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.15 (dd, 1H, $J_{OH,5'a} = 6.2$ Hz, $J_{OH,5'b} = 5.1$ Hz, OH-5′), 5.16 (d, 1H, $J_{OH,3'} = 4.8$ Hz, OH-3′), 5.30 (d, 1H, $J_{OH,2'} = 6.5$ Hz, OH-2′), 6.12 (bd, 1H, $J_{1',2'} = 6.6$ Hz, H-1′), 6.67 (dd, 1H, $J_{5,6} = 3.8$ Hz, $J_{5,LR} = 0.5$ Hz, H-5), 7.64 ppm (d, 1H, $J_{6,5} = 3.8$ Hz, H-6); ^{13}C NMR (150.9 MHz, [D$_6$]DMSO): $\delta = 21.3$ (CH_3-4), 25.6 (CH_3-2), 62.0 (CH_2-5′), 71.0 (CH-3′), 73.9 (CH-2′), 85.4 (CH-4′), 86.9 (C-1′), 100.1 (CH-5), 115.7 (C-4a), 126.0 (CH-6), 151.3 (C-7a), 159.0 (C-4), 159.7 ppm (C-2); IR (ATR): $\tilde{\nu} = 3400$, 3254, 3142, 3119, 2938, 2928, 1594, 1572, 1517, 1470, 1440, 1414, 1373, 1081, 1061, 1045, 1036, 896, 784, 738 cm^{-1}; MS (ESI) *m/z* (%): 280 (100) $[M+H]^+$, 302 (10) $[M+Na]^+$; HRMS (ESI) for $C_{13}H_{18}O_4N_3$ $[M+H]^+$ calcd: 280.12918, found: 280.12923; Anal. calcd for $C_{13}H_{17}O_4N_3 \cdot 0.9\,H_2O$: C 52.84, H 6.41, N 14.22, found: C 52.58, H 6.18, N 13.96.

2-Chloro-4-methyl-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (7h). Compound **23** (250 mg, 0.55 mmol) was treated according to general procedure A and the residue subjected to chromatography on silica ($CHCl_3$/MeOH, 10:1) to afford compound **7h** as a white solid after recrystallization from H_2O/MeOH 4:1 (145 mg, 88%): mp: 196–199 °C; $[\alpha]_D^{20} = -44.2$ ($c = 0.199$, DMSO); ^{1}H NMR (500 MHz, [D$_6$]DMSO): $\delta = 2.66$ (s, 3H, CH_3), 3.55 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.5$ Hz, $J_{5'a,4'} = 4.0$ Hz, H-5′a), 3.62 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.3$ Hz, H-5′b), 3.92 (m, 1H, H-4′), 4.09 (m, 1H, H-3′), 4.39 (m, 1H, H-2′), 5.03 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.4$ Hz, OH-5′), 5.22 (d, 1H, $J_{OH,3'} = 4.9$ Hz, OH-3′), 5.40 (d, 1H, $J_{OH,2'} = 6.4$ Hz, OH-2′), 6.09 (d, 1H, $J_{1',2'} = 6.3$ Hz, H-1′), 6.83 (d, 1H, $J_{5,6} = 3.7$ Hz, H-5), 7.83 ppm (d, 1H, $J_{6,5} = 3.8$ Hz, H-6); ^{13}C NMR (125.7 MHz, [D$_6$]DMSO): $\delta = 21.3$ (CH_3), 61.7 (CH_2-5′), 70.8 (CH-3′), 74.2 (CH-2′), 85.6 (CH-4′), 86.7 (CH-1′), 101.0 (CH-5), 117.3 (C-4a), 127.4 (CH-6), 151.9 and 152.2 (C-2,7a), 162.1 ppm (C-4); IR (ATR): $\tilde{\nu} = 3435$, 3330, 3120, 2967, 2945, 2917, 2889, 1594, 1566, 1513, 1458, 1403, 1289, 1243, 1159, 1088, 1073, 1051, 900, 739, 733, 722 cm^{-1}; MS (ESI) *m/z* (%): 322 (100) $[M+Na]^+$; HRMS (ESI) for $C_{12}H_{15}O_4N_3Cl$ $[M+H]^+$ calcd: 300.07456, found: 300.07461; Anal. calcd for $C_{12}H_{14}O_4N_3Cl \cdot 0.15\,H_2O$: C 47.66, H 4.77, N 13.89, found: C 47.98, H 4.67, N 13.54.

2-Fluoro-4-methyl-7-(β-D-ribofuranosyl)-7*H*-pyrrolo[2,3-*d*]pyrimidine (8h). To a solution of HF·pyridine (70%, 2 mL) at −20 °C was added compound **5h** (302 g, 1.08 mmol), followed by *tert*-butyl nitrite (0.19 mL, 1.62 mmol) dropwise. After 30 min of stirring at −20 °C, mixture was diluted with EtOAc (15 mL) and HF neutralized with $CaCO_3$ and aqueous $NaHCO_3$ (sat, 15 mL) to neutral pH. Mixture was filtered on a pad of Celite, and extracted with EtOAc (20 mL). The organic extract was dried over $MgSO_4$, filtered, evaporated, and the residue subjected to chromatography on silica ($CHCl_3$/MeOH, 20:1) to afford **8h** (99 mg, 32%) as a beige solid after lyophilization: mp: 163–167 °C; $[\alpha]_D^{20} = -41.9$ ($c = 0.174$, DMSO); ^{1}H NMR (600.1 MHz, [D$_6$]DMSO): $\delta = 2.66$ (s, 3H, CH_3-4), 3.55 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'a,OH} = 5.5$ Hz, $J_{5'a,4'} = 4.0$ Hz, H-5′a), 3.63 (ddd, 1H, $J_{gem} = 11.9$ Hz, $J_{5'b,OH} = 5.4$ Hz, $J_{5'b,4'} = 4.1$ Hz, H-5′b), 3.92 (td, 1H, $J_{4',5'a} = J_{4',5'b} = 4.0$ Hz, $J_{4',3'} = 3.2$ Hz, H-4′), 4.10 (tdd, 1H, $J_{3',2'} = J_{3',OH} = 5.0$ Hz, $J_{3',4'} = 3.2$ Hz, $J_{3',1'} = 0.4$ Hz, H-3′), 4.37 (td, 1H, $J_{2',1'} = J_{2',OH} = 6.3$ Hz, $J_{2',3'} = 5.1$ Hz, H-2′), 5.02 (t, 1H, $J_{OH,5'a} = J_{OH,5'b} = 5.4$ Hz, OH-5′), 5.19 (d, 1H, $J_{OH,3'} = 4.9$ Hz, OH-3′), 5.38 (d, 1H, $J_{OH,2'} = 6.5$ Hz, OH-2′), 6.04 (d, 1H, $J_{1',2'} = 6.2$ Hz, H-1′), 6.83 (dd, 1H, $J_{5,6} = 3.8$ Hz, $J_{5,LR} = 0.6$ Hz, H-5), 7.78 ppm (d, 1H, $J_{6,5} = 3.8$ Hz, H-6); ^{13}C NMR (150.9 MHz, [D$_6$]DMSO): $\delta = 21.3$ (CH_3-4), 61.7 (CH_2-5′), 70.7 (CH-3′), 74.2 (CH-2′), 85.5 (CH-4′), 86.9 (C-1′), 101.2 (CH-5), 116.8 (d, $J_{C,F} = 3.7$ Hz, C-4a), 127.1 (d, $J_{C,F} = 3.6$ Hz, CH-6), 152.4 (d, $J_{C,F} = 16.3$ Hz, C-7a), 158.3 (d, $J_{C,F} = 206.0$ Hz, C-2), 162.9 ppm (d, $J_{C,F} = 15.1$ Hz, C-4); ^{19}F NMR (470.3 MHz, [D$_6$]DMSO): $\delta = -50.90$ ppm (s, 1F, F-2); IR (ATR): $\tilde{\nu} = 3356$, 3115, 2927, 2876, 2856, 1607, 1578, 1518, 1476, 1430, 1383, 1347, 1295, 1205, 1085, 1053, 897, 796, 735 cm^{-1}; MS (ESI) *m/z* (%): 284 (5) $[M+H]^+$, 306 (100) $[M+Na]^+$; HRMS (ESI) for $C_{12}H_{14}O_4N_3FNa$ $[M+Na]^+$ calcd: 306.08606, found: 306.08609; Anal. calcd for $C_{12}H_{14}O_4N_3F{\cdot}0.75\,H_2O$: C 48.57, H 5.26, N 14.16, found: C 48.83, H 4.99, N 13.78.

Biological assays

MTT cytotoxicity assays. Cells were maintained in Nunc/Corning 80 cm^2 plastic tissue culture flasks and cultured in DMEM/RPMI-1640 cell culture medium (5 g L^{-1} glucose, 2 mM glutamine, 100 U mL^{-1} penicillin, 100 μg mL^{-1} streptomycin, 10% fetal calf serum, and $NaHCO_3$). Cell suspensions were prepared and diluted according to the particular cell type and the expected target cell density (25 000–30 000 cells per well based on cell growth characteristics). MTT assays were performed as described, and IC_{50} (50% cytotoxic concentration) values were calculated from appropriate dose–response curves.[5]

Enzyme preparation and inhibitor testing. Expression and purification of human and Mtb ADK were performed as previously described.[7b,9] Compounds were tested for inhibition of human and Mtb ADK using previously established methods.[8,9]

Antimycobacterial susceptibility testing. Compounds were tested for antimycobacterial activity against Mtb 331/88 (H37Rv) as previously described.[9] The micro-method was used to determine the minimum inhibitory concentration (MIC) values, which were determined after incubation at 37 °C for 14 and 21 days. The first-line anti-TB drug isoniazid (INH) was used as a reference compound.

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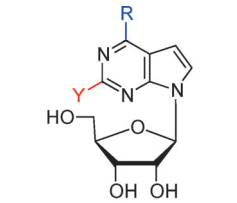
2-Substituted 6-(Het)aryl-7-deazapurine Ribonucleosides: Synthesis, Inhibition of Adenosine Kinases, and Antimycobacterial Activity



Y = NH_2, CH_3, Cl, F
R = heteroaryl, aryl, methyl

Specific for Mtb ADK: A series of diverse 2-substituted 6-heteroaryl-7-deazapurine ribonucleosides was prepared and the title compounds were found to be potent and selective inhibitors of *Mycobacterium tuberculosis* (but not human) adenosine kinase. Unfortunately, their antimycobacterial activity was observed to be weak, probably due to poor uptake or parallel biosynthesis.