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Synthesis and Structural Analysis of 4-Deoxy-4-(hydroxyphosphinyl and phenylphosphinyl)-D-ribofuranoses

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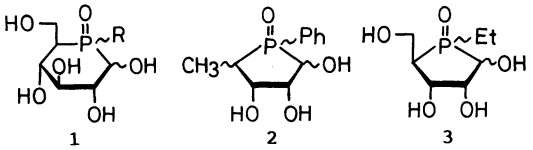
Methyl 2,3-*O*-isopropylidene-β-D-ribopyranoside gave efficiently (in 4 steps) methyl 4-deoxy-4-[dimethoxyphosphinyl and (methoxy)phenylphosphinyl]-2,3-*O*-isopropylidene-β-D-ribopyranosides (ca. 30% overall yield). These were led (in 2—3 steps) to the title compounds and then converted into 1,2,3,5-tetra-*O*-acetyl-4-deoxy-4-(methoxyphosphinyl and phenylphosphinyl)-D-ribofuranoses, whose structures and $^3T_2$ (and $^2T_3$) conformations were established by spectroscopy.

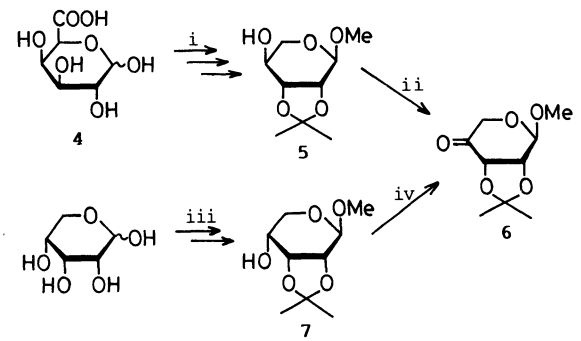
Various sugar analogues possessing a phosphorus atom in place of oxygen in the hemiacetal ring have been prepared in recent years;[1–6] e.g., 5-deoxy-5-phosphinyl-D-glucopyranoses (**1**).[4,7] These compounds are of interest in view of their physicochemical properties as well as potential biological activity.[1] As for analogues of D-ribose type, 4,5-dideoxy-4-(phenylphosphinyl)- (**2**)[8] and 4-deoxy-4-(ethylphosphinyl)-D-ribofuranoses (**3**)[3] have been synthesized in lengthy steps as a mixture with their L-lyxofuranose analogues (particularly in the case of **2**). We wish to report herein our detailed studies on synthesis and structural analysis of D-ribofuranose analogues having a hydroxyphosphinyl group in the ring,[9] as well as of those having PO(Ph) as a representative arylphosphinyl group in the ring. Although PO(OH)-in-ring sugar analogues were usually found more difficult to prepare than those having an alkyl- or arylphosphinyl group in the ring,[1,3,10] both 4-deoxy-4-(hydroxyphosphinyl and phenylphosphinyl)-D-ribofuranoses have become available in almost comparably good yield. The present synthesis also clarifies the ambiguity that existed in the previous synthetic schemes concerning the epimerization caused by hydride reduction of some intermediates.[4,7]



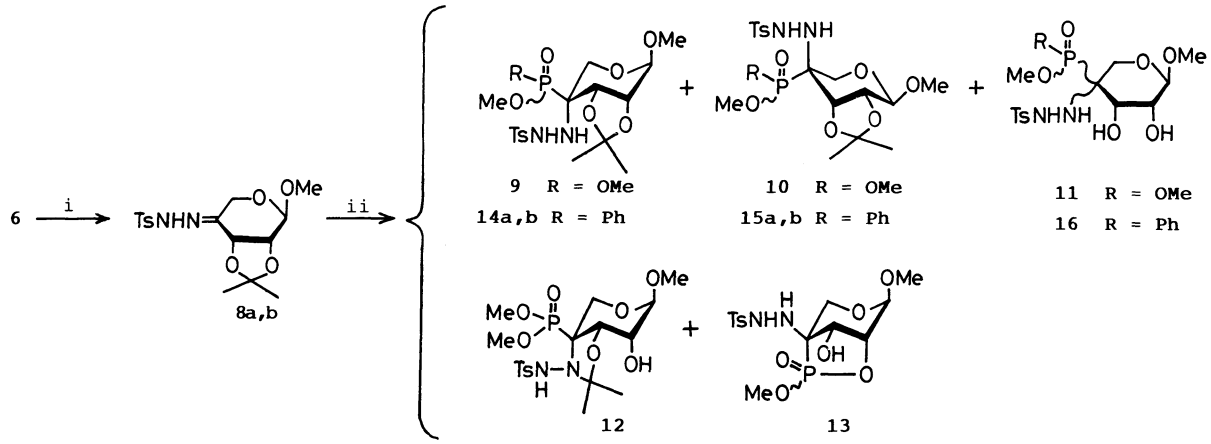
Results and Discussion

For synthesis of the D-ribofuranose analogues **3**,[3] methyl 2,3-*O*-isopropylidene-α-L-lyxopyranoside (**5**, prepared,[3,11] with some difficulty, from D-galacturonic acid **4** in 4 steps) was used as the precursor of the preparation of the starting material, (methyl 2,3-*O*-isopropylidene-β-D-*erythro*-pentopyranosid)-4-ulose (**6**)[3] (Scheme 1). However, we have now found it more convenient to utilize instead methyl 2,3-*O*-isopropylidene-β-D-ribopyranoside (**7**) for preparation of **6**, because **7** is readily available in quantities, though along with the chromatographically separable 3,4-*O*-isopropylidene isomer, from D-ribose in 2 steps.[12] Oxidation of **7** with pyridinium chlorochromate (PCC) in dichloromethane in the presence of Molecular Sieves (3A) now furnished **6** more effectively than the previous oxidation procedure for **5** (see Scheme 1).

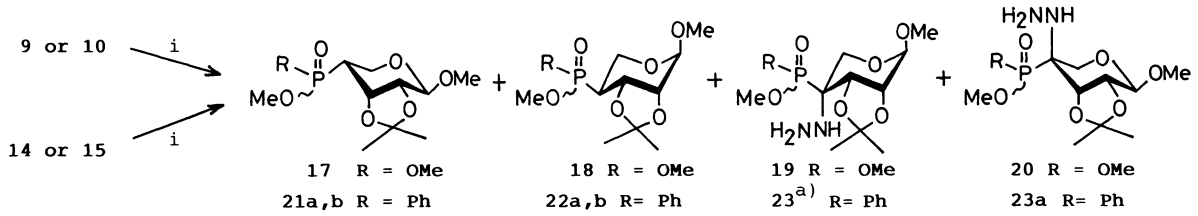
Compound **6** was then converted into the tosylhydrazones **8a,b**[3] (as a 4:1 mixture of *Z* and *E* isomers) in 95% yield. This in turn was treated with an excess of dimethyl phosphonate in the presence of trifluoromethanesulfonic acid at 25 °C for 5 h, giving the (4*S*)-phosphonate **9** (56% isolated yield) and the (4*R*)-epimer **10** (10%), together with minor proportions of by-products **11** (10%), **12** (4%), and **13** (1.5%). These compounds were chromatographically separable, and their structural and conformational assignments (see Scheme 2) were made on the basis of spectral data (in particular by ^{1}H NMR, see the complete assignments given in the Experimental section). For distinction between the two major products **9** and **10**, the following characteristic δ, ^3J, and ^4J values of their ^{1}H NMR data were taken into consideration: δ 4.85 (H-1), $J_{1,2}$=4.7 Hz, and $J_{2,P}$=1.2 Hz for **9** (predominantly in $^1C_4$ form) and δ 4.17 (H-1), $J_{1,2}$=7.2 Hz, and $J_{3,5e}$=1.5 Hz for **10** ($^4C_1$). Among the minor products, **11** was readily protected again with 2,2-dimethoxypropane to



Scheme 1. Preparation of **6**. i, Refs. 3 and 11, 38%. ii, DMSO–$(COCl)_2$–TEA, 74% (Ref. 3). iii, Ref. 12, 15%. iv, PCC/CH_2Cl_2, 94%.



Scheme 2. Preparation and Conformations of **9**—**16**. i, $TsNHNH_2$, 95%. ii, $HP(O)(OMe)_2$ or $PhP(O)H(OMe)/CF_3SO_3H$.



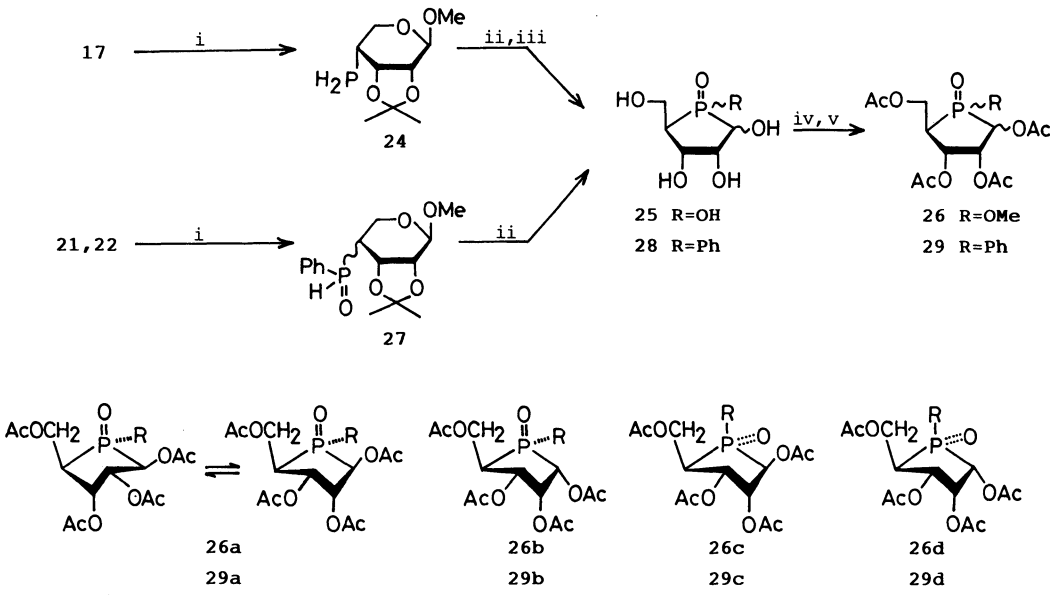
Scheme 3. Preparation of **17**—**23**. i, $NaBH_4$/THF. a) A 7:1 mixture of (4*S*)- and (4*R*)-epimers.

reproduce the above 2,3-*O*-isopropylidene compounds **9** and **10**.

Similarly, the addition of methyl phenylphosphinate to **8a,b** took place smoothly, affording (4*S*)-phosphinates **14a,b** (60% yield) and (4*R*)-epimers **15a,b** (6%), together with the deprotected products **16** (9%), each being a mixture of inseparable, two diastereomers due to asymmetry of the phosphorus atom. Their structures and the preferred conformations shown in Scheme 2 were established as described above (for **9**—**11**); note that no minor products corresponding to **12** and **13** were obtained in this case. This is the first time that both epimers of the phosphonate or phosphinate addition products have been isolated and characterized in this type of synthetic scheme for the sugar ring-C–P bond formation.[1)]

Reductive removal of the tosylhydrazino group from these addition products were then studied in detail. Thus, upon treatment of the major (4*S*)-epimer **9** with sodium borohydride in THF at 25 °C for 12 h, it was found that methyl 4-deoxyl-4-(dimethoxyphosphinyl)-2,3-*O*-isopropylidene-β-D-ribopyranoside (**17**) and α-L-lyxopyranoside (**18**) were produced in a ratio of 85:15, respectively (Scheme 3). When the minor (4*R*)-epimer **10** was subjected to the same reduction, **17** and **18** were obtained notably in almost the same ratio as above. The structural assignments of these C-4 epimers were based on their spectral data (see the Experimental section); the following characteristic ^1H NMR data in particular served for clear distinction between them, δ 4.37 (H-1), $J_{3,4}$=3.0 Hz, and $J_{3,5e}$=0.8 Hz for **17** ($^4C_1$) vs. δ 4.79 (H-1), $J_{1,5e}$=2.0 Hz, $J_{2,P}$=1.6 Hz, and $J_{3,4}$=8.4 Hz for **18** ($^1C_4$). Besides **17** and **18**, a minor proportion of detosylated hydrazino compounds **19** (12%) and **20** (7%) were produced from **9** and **10**, respectively. By the analysis of the NMR data, all of these compounds (**17**—**20**) are most likely to have conformations (in $CDCl_3$) in which the phosphonate group is predominantly linked equatorially (see Scheme 3).

Similar results were obtained for the reductive cleavage of 4-deoxy-4-[(methoxy)phenylphosphinyl] compounds **14** and **15**, thus either of these compounds providing the D-ribopyranosides **21a,b** and L-lyxopyranosides **22a,b** in a ratio of 88:12, besides a minor amount (7% yield) of hydrazino compounds **23** consisting of a ca. 1:7 mixture of (4*R*)- and (4*S*)-epimers (Scheme 3). Furthermore, the borohydride reduction of a pure epimer **15a**, which was the only crystalline compound among the four diastereomers **14a,b** and **15a,b**, was found to give the same ratio (88:12) of two pure diastereomers **21a** and **22a**, together with a minor proportion of a pure (4*R*)-4-hydrazino-epimer **23a**; note that no other isomers **21b** and **22b** were produced from **15a**. These results therefore indicated that an epimerization took place at C-4 (but not at the P atom) during the borohydride



Scheme 4. Synthesis and Conformations of **26** and **29**. i, SDMA/benzene. ii, 0.5 M HCl-*i*PrOH. iii, aq H_2O_2. iv, CH_2N_2/MeOH–DMSO. v, Ac_2O–Pyridine.

reduction of all of these hydrazino compounds **9**, **10**, **14**, and **15**, resulting in the formation of the major products **17** and **21a,b** presumably through a thermodynamically controlled process.

The D-ribose type precursor **17** was then reduced with an excess (3 equiv) of sodium dihydrobis(2-methoxyethoxy)aluminate (SDMA)[13] in benzene at 5 °C for 1 h, giving solely methyl 4-deoxy-2,3-*O*-isopropylidene-4-phosphino-β-D-ribopyranoside **24** (Scheme 4); it should be noticed that no epimerization occurred at C-4 of **17** with SDMA (see below), in contrast to the equilibration (at C-5) observed in the case of 5-deoxy-5-[ethyl(methoxy)phosphinyl]-α-D-*xylo*-hexofuranoses to give predominantly 5-deoxy-5-(ethylphosphinyl)-L-idopyranoses.[5c]

The extremely air-sensitive compound **24** was promptly hydrolyzed under argon with mineral acid at 90 °C for 1 h to effect deprotection and the subsequent ring transposition. Oxidation of the resulting air-sensitive[10] phosphinediyl-in-ring compound with hydrogen peroxide at 25 °C for 1 d afforded 4-deoxy-4-(hydroxyphosphinyl)-D-ribofuranoses (**25**). For isolation and characterization, **25** were converted into its 4-(methoxyphosphinyl) tetraacetates **26** by the usual method (in 17% overall yield from **17**) (see Scheme 4). Rechromatography of **26** in a column of silica gel with 19:1 ethyl acetate–ethanol as the eluant afforded pure 1,2,3,5-tetra-*O*-acetyl-4-deoxy-4-[(*R*)-methoxyphosphinyl]-β-D-ribofuranose (**26a**, 6.3% yield from **17**), its α-anomer **26b** (3.3% yield), and the 4-[(*S*)-*P*]-β-isomer **26c** (2.8%), and its α-anomer **26d** (1.7%). Structures of **26a—d** were established by the analysis of their spectral data (Experimental section) and the approximate conformations of these isomers shown in Scheme 4 were derived from the analysis of 500 MHz ^{1}H NMR spectra (see below). The fact that the products **26a—d** were all D-ribofuranose configuration proved that no epimerization actually took place at C-4 of **26** during the SDMA reduction to yield **24**.

The conversion of 4-[(methoxy)phenylphosphinyl] compounds **21** and **22** into the corresponding PO(Ph)-in-ring D-ribofuranose analogues **28** was conducted by the same procedures described above. Namely, the SDMA reduction of **21** (or **22**) gave the 4-(phenylphosphinyl)-β-D-*erythro*-pentopyranoside **27**, which was then treated with dilute acid to provide predominantly 4-deoxy-4-(phenylphosphinyl)-D-ribofuranoses (**28**). Characterization of **28** was made as the 4-deoxy-4-(phenylphosphinyl) tetraacetates **29a—d** (see Scheme 4) as described above for **26a—d**.

^{1}H NMR Spectral Analysis of Tetra-*O*-acetyl-4-deoxy-4-(methoxy- and phenylphosphinyl)-D-ribofuranoses (26a—d and 29a—d). For the structural assignments of these new products, the chemical shift of each proton signal and the dependence of $^2J_{H,P}$, $^3J_{H,P}$, $^3J_{H,H}$, and $^4J_{H,H}$ values on their dihedral angles were carefully taken into consideration; the precise parameters obtained at 500 MHz for these compounds are summarized in Table 1. Some characteristic features of **26** and **29** are discussed here in detail, although in many cases they closely resemble those of the previously obtained **2** and **3**.

(1) The orientation of the ring P=O group can be established by the δ values of H-4 in combination with

Table 1. ^{1}H NMR (500 MHz) Parameters for **26** and **29** in $CDCl_3$

Compd	Chemical shift (δ)										
	H-1	H-2	H-3	H-4	H-5	H′-5	Ac-1,2,3,5[a]	POMe	Ph(o)	Ph(m)	Ph(p)
26a	4.94	5.58	5.42	2.66	4.43	4.28	2.19, 2.10, 2.10, 2.09	3.92			
26b	5.20	5.72	5.24	2.76	4.36	4.36	2.14, 2.09, 2.09, 2.06	3.90			
26c	5.03	5.43	5.27	2.84	4.33	4.22	2.15, 2.13, 2.11, 2.08	3.80			
26d	4.81	5.75	5.07	2.96	4.37	4.23	2.19, 2.16, 2.07, 2.06	3.89			
29a	5.09	5.75	5.64	3.02	4.52	4.44	2.20, 2.12, 2.10, 1.90		7.87	7.56	7.62
29b	5.48	5.94	5.56	3.10	4.51	4.44	2.21, 2.10, 1.78, 1.77		7.89	7.52	7.69
29c	5.32	5.64	5.49	3.23	4.18	4.03	2.21, 2.13, 1.85, 1.77		7.76	7.55	7.62
29d	5.28	5.95	5.20	3.32	4.14	3.86	2.26, 2.11, 2.09, 1.83		7.77	7.56	7.62

	Coupling constant (Hz)												
	$J_{1,2}$	$J_{1,4}$	$J_{1,P}$	$J_{2,3}$	$J_{2,P}$	$J_{3,4}$	$J_{3,P}$	$J_{4,5}$	$J_{4,5'}$	$J_{4,P}$	$J_{5,5'}$	$J_{5,P}$	$J_{5',P}$	J_{POMe}
26a	6.4	0.5	6.6	3.9	11.1	5.7	18.0	6.7	7.2	16.7	11.8	12.8	13.2	11.5
26b	4.7	0	7.7	3.3	31.0	11.1	2.5	6.8	6.8	17.7	—	15.8	15.8	11.2
26c	3.8	0.5	5.5	3.7	21.3	8.3	8.7	7.0	8.0	18.8	11.3	10.1	9.8	10.7
26d	4.9	0	6.4	3.2	32.5	11.2	0.8	6.7	7.9	19.0	11.3	17.5	10.1	11.2
29a	4.6	0.5	2.2	3.8	14.8	8.2	9.7	8.0	7.0	7.8	11.5	9.4	15.0	b)
29b	5.1	0	11.7	3.3	27.5	11.6	1.7	6.0	8.7	8.4	11.4	18.7	10.0	
29c	3.2	0.8	7.8	3.9	16.9	10.2	5.1	6.8	8.3	22.2	11.6	17.5	10.7	
29d	4.7	0	1.4	3.2	27.4	11.6	0.8	6.1	8.3	23.0	11.6	17.8	12.2	

a) The assignments of acetoxyl groups may have to be interchanged. b) J Values for P-Ph: $J_{P,o}$=12.5, $J_{P,m}$=3.5, $J_{P,p}$=1.5, $J_{o,p}$=7.8, $J_{m,p}$=7.5, and $J_{o,p}$=1.5 Hz. Compounds **29b—d** show similar J values.

the $J_{4,P}$ values. In the present study, a slightly upfield shift of these signals with a smaller $J_{4,P}$ value† is observed for **26a,b** and **29a,b**, thus showing an almost trans relationship between H-4 and the ring P=O for these compounds. The cis or gauche relationship for **26c,d** and **29c,d** was confirmed by the large $J_{4,P}$ values.† The anomeric orientation of C-1 is similarly derived from the magnitudes of δ values of H-1 and the $J_{1,P}$ values as well as the presence of $J_{1,4}$. Namely, a relatively large values of δ and $J_{1,P}$† for H-1 of **26b,c** and **29b,c** indicate the cis (or gauche) relationship of the H-1 and P=O groups, whereas the small $J_{1,P}$ values† point out an almost trans relationship for **26a,d** and **29a,d**. The presence of a small long-range W-coupling ($J_{1,4}$) observed for **26a,c** and **29a,c** indicates the β-configuration of H-1. Therefore, combination of these data readily permits unambiguous establishment of the configurations of H-1 as well as ring-phosphorus atom of aldopentofuranoses.

(2) Compounds **26b—d** and **29b—d** have a large $J_{2,P}$ values and small $J_{3,P}$ and thus are considered to exist preponderantly in the E_2 (or readily variable $^3T_2$) conformation. The concurrent differences in the δ values of H-2 (larger) and H-3 (smaller) further support their respective quasi-equatorial and quasi-axial orientation. Compounds **26a** and **29a** have rather close magnitudes of $J_{2,P}$ and $J_{3,P}$ and the δ values of H-2 and H-3. This suggests an averaging between the interconverting $^3T_2$ and $^2T_3$ conformations with a slight tendency towards $^3T_2$ and $^2T_3$ form (respectively for **26a** and **29a**), judging from the magnitudes of the corresponding δ and J values. The conformations of these P-in-ring D-ribofuranoses are of interest in view of the reported monocyclic furanoid derivatives including many nucleosides and nucleotides which are regarded as existing as rapidly interconverting conformation in solution, favoring puckering the C-2–C-3 region of the furanoid ring.[14]

The present findings are believed to have clearly proved the equilibrated epimerization caused by the hydride reagents in favor of the formation of the key intermediate methyl 4-deoxy-4-phosphinyl-β-D-ribopyranosides, as well as to have established an efficient synthetic scheme for preparation of D-ribofuranose analogues having various kinds of phosphinyl or phosphino group in the hemiacetal ring. The extension of this work including improvement of the yields of the ring-transposition steps and preparation of D-ribofuranose analogues having various other kinds of *P*-substituents, as well as biological evaluation of the compounds, is in progress.

Experimental

Melting points were determined with a Yanagimoto MP-S3 instrument and were uncorrected. All reactions were monitored by TLC (Merck silica gel 60F, 0.25 mm) with (*A*) AcOEt, (*B*) 1:1 AcOEt–hexane, (*C*) 19:1 AcOEt–EtOH, and (*D*) 5:3:1 2-propanol–AcOEt–water as the eluant; components were detected by exposing the plates to UV light and/or by spraying them with 20% sulfuric acid–ethanol, with subsequent heating. Column chromatography was

† For these features, an exception lies in the parameters for the methoxyphosphinyl compounds **26a—d**, having intermediate, close magnitudes of $J_{1,P}$ and $J_{4,P}$. These unusual parameters have also been observed for per-*O*-acetyl-5-deoxy-5-(methoxyphosphinyl)-D-xylo-[10] and D-glucopyranoses.[4]

performed by Wako C-200 silica gel. The ^{1}H NMR spectra were measured in $CDCl_3$ (unless otherwise specified) with a Hitachi R-600 (60 MHz) or Varian VXR-500 instrument (500 MHz, the CS-NMR Lab., Okayama Univ.) at 27 °C. Chemical shifts (at 500 MHz unless otherwise stated) were recorded as δ values relative to tetramethylsilane as the internal standard. The assignments of all signals were made by employing a first-order analysis with the aid of decoupling technique and, when necessary, the parameters were confirmed by a computer-assisted simulation analysis. The mass spectra (EI, unless otherwise specified) were taken on a Shimadzu LKB-9000 low-resolution or a JEOL JMX-HX100 high-resolution instrument and were given in terms of m/z (rel intensity) compared with the base peak.

(Methyl 2,3-*O*-Isopropylidene-β-D-*erythro*-pentopyranosid)-4-ulose[3] (6). To a stirred suspension of finely powdered Molecular Sieves 3A (20 g) and PCC (10.0 g, 46.4 mmol) in dry CH_2Cl_2 (150 cm^3) was added a soln of **7**[12] (4.29 g, 21.0 mmol) in dry CH_2Cl_2 (50 cm^3) at 0 °C. The mixture was stirred at 20 °C for 4 h and then 2-propanol (5 cm^3) was added at 0 °C. The mixture was stirred at 20 °C for 2 h, triturated with ether (500 cm^3) for 2 h, and the ppt was filtered off through activated carbon. The filtrate was evaporated in vacuo and the residue was purified by short-pass chromatography with 2:1 AcOEt–hexane as an eluant, giving **6** as a colorless syrup (3.98 g, 94%, lit,[3] 74% from **5**): R_f=0.60 (*B*); ^{1}H NMR[15] δ=1.37, 1.51 (3H each, 2s, CMe_2), 3.47 (3H, s, MeO-1), 4.13, 4.18 (1H each, 2d, $J_{5,5'}$=16.8 Hz, H-5,5′), 4.41 (1H, d, $J_{2,3}$=6.8 Hz, H-3), 4.42 (1H, dd, $J_{1,2}$=0.8 Hz, H-2), and 4.78 (1H, br s, H-1).

(Methyl 2,3-*O*-Isopropylidene-β-D-*erythro*-pentopyranosid)-4-ulose (*Z*)- and (*E*)-4-Tosylhydrazones[3] (8a,b). A slightly modified procedure was employed to give a better yield of the product. Thus, to a soln of **6** (3.94 g, 19.5 mmol) in absolute methanol (100 cm^3) was added tosylhydrazine (4.00 g, 21.5 mmol) under stirring at room temp. After 6 h, the mixture was evaporated in vacuo. The residue was diluted with CH_2Cl_2, washed with dil HCl, aq $NaHCO_3$, and then with water. The organic layer was dried (Na_2SO_4) and evaporated in vacuo. The residue was purified by column chromatography with 1:1 AcOEt–hexane, giving **8** as a colorless amorphous solid (6.84 g, 95%): R_f=0.50 (**8a**), 0.42 (**8b**) (*B*) (4:1, lit,[3] 91% yield, 1:1); ^{1}H NMR[15] for **8a** (*Z*) δ=1.05, 1.33 (3H each, 2s, CMe_2), 2.41 (3H, s, MeC_6–S), 3.41 (3H, s, MeO-1), 4.06, 4.20 (1H each, 2d, $J_{5,5'}$=14.8 Hz, H-5,5′), 4.13 (1H, dd, $J_{2,3}$=5.8, $J_{1,2}$=0.8 Hz, H-2), 4.83 (1H, d, H-3), 4.87 (1H, br s, H-1), 7.28, 7.80 (2H each, 2br d, J=8.4 Hz, C_6H_4–S), and 9.69 (1H, br s, NH); for **8b** (*E*) δ=1.32, 1.45 (3H each, 2s, CMe_2), 2.43 (3H, s, MeC_6–S), 3.34 (3H, s, MeO-1), 4.16 (1H, br d, $J_{2,3}$=7.4 Hz, H-2), 4.26 (2H, s, H-5,5′), 4.55 (1H, br s, H-1), 4.67 (1H, d, H-3), 7.31, 7.83 (2H each, 2br d, J=8.3 Hz, C_6H_4–S), and 7.61 (1H, br s, NH), for the reasoning behind the respective assignments of *Z* and *E* isomers to **8a** and **8b**, see Ref. 16.

Methyl (4*R* and 4*S*)-4-Deoxy-4-(dimethoxyphosphinyl)-4-(2-tosylhydrazino)-β-D-*erythro*-pentopyranosides (9—13). To a mixture of **8** (1.28 g, 3.76 mmol) and dimethyl phosphinate (3.30 g, 30.0 mmol) was added trifluoromethanesulfonic acid (0.100 cm^3, 1.13 mmol) at 0 °C under argon, followed by stirring at 25 °C for 5 h. The mixture was diluted with CH_2Cl_2, washed with saturated aq $NaHCO_3$ and then with water, dried (Na_2SO_4), and evaporated in vacuo. The residue was chromatographed on a silica-gel column with 2:1 AcOEt–hexane (which was gradually changed to AcOEt), giving **9—13**.

9 [(4*S*)-2,3-*O*-Isopropylidene-epimer]: Colorless syrup (1.01 g, 56%); R_f=0.33 (*A*); ^{1}H NMR δ=1.32, 1.35 (3H each, 2s, CMe_2), 2.42 (3H, s, MeC_6–S), 3.47 (3H, s, MeO-1), 3.77, 3.84 [3H each, 2d, J_{POMe}=10.7, 10.5 Hz, P(OMe)$_2$], 3.88 (1H, dd, $J_{5e,5a}$=12.6, $J_{5a,P}$=7.0 Hz, H-5a), 4.03 (1H, ddd, $J_{2,3}$=6.7, $J_{1,2}$=4.7, $J_{2,P}$=1.2 Hz, H-2), 4.14 (1H, dd, $J_{5e,P}$=11.4 Hz, H-5e), 4.30 (1H, br s, NH-4), 4.59 (1H, dd, $J_{3,P}$=8.5 Hz, H-3), 4.85 (1H, d, H-1), 6.40 (1H, br s, TsNH), and 7.30, 7.80 (2H each, 2br d, J=8.1 Hz, C_6H_4–S); MS m/z 480 (M^+; 0.7), 465 (7), 325 (7), 293 (10), 221 (30), 207 (29), 193 (100), 178 (30), 165 (51), 137 (27), 109 (46), and 91 (55).

Found: m/z 480.1341. Calcd for $C_{18}H_{29}N_2O_9PS$: M, 480.1331.

10 [(4*R*)-2,3-*O*-Isopropylidene-epimer]: Colorless needles (178 mg, 10%); R_f=0.23 (*A*); mp 156—157 °C (from AcOEt–hexane); ^{1}H NMR δ=1.33, 1.51 (3H each, 2s, CMe_2), 2.42 (3H, s, MeC_6–S), 3.47 (3H, s, MeO-1), 3.70 (1H, dt, $J_{5e,5a}$=12.9, $J_{5e,P}$=1.6, $J_{3,5e}$=1.5 Hz, H-5e), 3.76, 3.83 [3H each, 2d, J_{POMe}=10.8, 10.9 Hz, P(OMe)$_2$], 3.88 (1H, dd, $J_{1,2}$=7.2, $J_{2,3}$=5.1 Hz, H-2), 3.92 (1H, dd, $J_{5a,P}$=1.9 Hz, H-5a), 3.95 (1H, br s, NH-4), 4.17 (1H, d, H-1), 4.36 (1H, ddd, $J_{3,P}$=3.5 Hz, H-3), 6.58 (1H, br s, TsNH), and 7.32, 7.79 (2H each, 2br d, J=8.2 Hz, C_6H_4–S); MS m/z 465 (M−CH_3; 0.8), 325 (1.5), 293 (14), 281 (30), 221 (59), 207 (39), 178 (72), 165 (40), 149 (58), 109 (90), and 91 (100).

11: Pale yellow syrup (165 mg, 10%); R_f=0.15—0.08 (*A*); ^{1}H NMR (60 MHz) δ=2.40 (3H, s, MeC_6–S), 3.47 (3H, s, MeO-1), 3.0—3.6 (2H, m, HO-2,3), 3.77, 3.82 [3H each, 2d, J_{POMe}=11.0 Hz, P(OMe)$_2$], 3.7—4.6 (5H, m, H-2,3,5,5′, NH-4), 4.70 (1H, br d, $J_{1,2}$=3.0 Hz, H-1), 6.9—7.2 (1H, m, TsNH), and 7.30, 7.84 (2H each, 2d, J=8.1 Hz, C_6H_4–S).

12 [(4*S*)-3-*O*:4-*N*-Isopropylidene-isomer]: Colorless prisms (68 mg, 4%); R_f=0.28 (*A*); mp 153—154 °C (from AcOEt); ^{1}H NMR δ=0.62, 1.33 (3H each, 2s, CMe_2), 2.33 (1H, br s, HO-2), 2.42 (3H, s, MeC_6–S), 3.46 (3H, s, MeO-1), 3.68 (1H, dd, $J_{1,2}$=6.5, $J_{2,3}$=3.0 Hz, H-2), 3.78, 3.97 [3H each, 2d, J_{POMe}=10.9, 11.0 Hz, P(OMe)$_2$], 3.80 (1H, dd, $J_{5e,5a}$=12.5, $J_{5a,P}$=3.5 Hz, H-5a), 4.06 (1H, dd, $J_{5e,P}$=4.2 Hz, H-5e), 4.52 (1H, d, H-1), 4.61 (1H, dd, $J_{3,P}$=15.6 Hz, H-3), 7.23 (1H, br s, TsNH), and 7.30, 7.82 (2H each, 2br d, J=8.3 Hz, C_6H_4–S); MS m/z 465 (M−CH_3; 2.5), 433 (2), 325 (2), 295 (3), 207 (32), 189 (55), 178 (55), 149 (58), 109 (60), and 91 (100).

Found: m/z 465.1120. Calcd for $C_{17}H_{26}N_2O_9PS$: M−CH_3, 465.1097.

13 [(4*R*)-4-(2-*O*-*Cyclo*-methoxyphosphinyl)-isomer]: Colorless prisms (23 mg, 1.5%); mp 202—204 °C decomp (from AcOEt); R_f=0.10 (*A*); ^{1}H NMR (in 9:1 $CDCl_3$–DMSO-d_6) δ=2.35 (3H, s, MeC_6–S), 2.50 (1H, br s, HO-3), 3.31 (3H, s, MeO-1), 3.71 (3H, d, J_{POMe}=11.1 Hz, POMe), 3.81 (1H, dd, $J_{5a,P}$=22.6, $J_{5e,5a}$=11.6 Hz, H-5a), 3.84 (1H, dd, $J_{5e,P}$=5.0 Hz, H-5e), 4.25 (1H, br s, NH-4), 4.34 (1H, dd, $J_{2,P}$=20.0, $J_{1,2}$=2.5, $J_{2,3}\simeq$0 Hz, H-2), 4.41 (1H, d, $J_{3,P}$=28.3 Hz, H-3), 4.71 (1H, d, $J_{1,2}$=2.5 Hz, H-1), 7.23, 7.69 (2H each, 2br d, J=8.2 Hz, C_6H_4–S), and 7.88 (1H, br s, TsNH).

Compound **11** (165 mg) was stirred at 25 °C for 8 h in 2,2-dimethoxypropane (5 cm^3) containing 4 M hydrochloric acid (1 M=1 mol dm^{-3}) in 1,4-dioxane (0.1 cm^3). The soln was neutralized with anhyd $NaHCO_3$, filtered, and evaporated in vacuo. The residue was purified by column chromatog-

raphy, giving **9** and **10** (153 mg in total, 85%).

Methyl (4*R* and 4*S*)-4-Deoxy-4-[(*R* and *S*)-(methoxy)-phenylphosphinyl]-4-(2-tosylhydrazino)-β-D-*erythro*-pentopyranosides (14—16). By the use of the same procedures as those for preparation of **9** and **10**, compound **8** (820 mg, 2.21 mmol) was treated with methyl phenylphosphinate (2.70 g, 17.3 mmol) and trifluoromethanesulfonic acid (0.060 cm^3, 0.68 mmol) at 20 °C for 10 h. Purification by column chromatography gave **14—16**.

14a,b {(4*S*)-2,3-*O*-Isopropylidene-4-[(*R* and *S*)-*P*]-diastereomers}: Colorless syrup (698 mg, 60%, a 2:1 mixture of **14a** and **14b**); R_f=0.50—0.46 (*A*); ^{1}H NMR for **14a** δ=1.23, 1.37 (3H each, 2s, CMe_2), 2.39 (3H, s, MeC_6-S), 3.43 (3H, s, MeO-1), 3.69 (3H, d, J_{POMe}=10.8 Hz, POMe), 3.79 (1H, dd, $J_{5e,5a}$=12.8, $J_{5a,P}$=7.5 Hz, H-5a), 3.86 (1H, dd, $J_{2,3}$=6.8, $J_{1,2}$=4.9 Hz, H-2), 3.94 (1H, dd, $J_{5e,P}$=10.7 Hz, H-5e), 4.35 (1H, dd, $J_{3,P}$=9.2 Hz, H-3), 4.58 (1H, br s, NH-4), 4.87 (1H, d, H-1), 6.62 (1H, br s, TsNH), 7.22, 7.71 (2H each, 2br d, *J*=8.3 Hz, C_6H_4-S), 7.49 [2H, m, $J_{o,m}$=7.6, $J_{m,p}$=7.3, $J_{P,m}$=3.6 Hz, Ph(*m*)], 7.63 [1H, m, $J_{o,p}$=$J_{P,p}$=1.5 Hz, Ph(*p*)], and 7.76 [2H, m, $J_{P,o}$=11.4 Hz, Ph(*o*)], for **14b** δ=1.36, 1.42 (3H each, 2s, CMe_2), 2.39 (3H, s, MeC_6-S), 3.47 (3H, s, MeO-1), 3.52 (1H, dd, $J_{5e,5a}$=12.8, $J_{5a,P}$=9.0 Hz, H-5a), 3.67 (3H, d, J_{POMe}=10.9 Hz, POMe), 3.74 (1H, dd, $J_{5e,P}$=14.9 Hz, H-5e), 4.06 (1H, dd, $J_{2,3}$=6.4, $J_{1,2}$=5.3 Hz, H-2), 4.58 (1H, br s, NH-4), 4.59 (1H, d, H-1), 4.75 (1H, dd, $J_{3,P}$=7.5 Hz, H-3), 6.52 (1H, br s, TsNH), 7.20, 7.61 (2H each, 2br d, *J*=8.3 Hz, C_6H_4-S), 7.53 [2H, m, Ph(*m*)], 7.65 [1H, m, Ph(*p*)], and 7.76 [2H, m, Ph(*o*)].

15a,b {(4*R*)-2,3-*O*-Isopropylidene-4-[(*R* and *S*)-*P*]-diastereomers}: Colorless syrup (70.3 mg, 6.3%), recrystallization of the syrup from AcOEt–hexane yielded **15a** (50.3 mg) as colorless needles, mp 172—173 °C; R_f=0.30 (*A*); ^{1}H NMR for **15a** δ=1.20, 1.43 (3H each, 2s, CMe_2), 2.40 (3H, s, MeC_6-S), 3.41 (3H, s, MeO-1), 3.59 (1H, dd, $J_{5e,5a}$=12.8, $J_{5a,P}$=2.2 Hz, H-5a), 3.65 (1H, dt, $J_{5e,P}$=1.0, $J_{3,5e}$=0.8 Hz, H-5e), 3.74 (3H, d, J_{POMe}=11.1 Hz, POMe), 3.99 (1H, dd, $J_{1,2}$=7.3, $J_{2,3}$=5.0 Hz, H-2), 4.03 (1H, d, H-1), 4.19 (1H, ddd, $J_{3,P}$=1.3, $J_{3,5e}$=0.8 Hz, H-3), 4.27 (1H, br s, NH-4), 6.83 (1H, br s, TsNH), 7.27, 7.75 (2H each, 2d, *J*=8.3 Hz, C_6H_4-S), 7.48 [2H, m, Ph(*m*)], 7.60 [1H, m, Ph(*p*)], and 7.84 [2H, m, Ph(*o*)]; MS *m/z* 511 ($M-CH_3$; 0.8), 371 (2.2), 327 (13), 263 (13), 224 (56), 195 (32), 183 (48), 155 (100), 141 (32), and 91 (47).

16: Pale yellow syrup (96 mg, 9%); R_f=0.22—0.10 (*A*); ^{1}H NMR (60 MHz) δ=2.40 (3H, s, MeC_6-S), 3.30, 3.33 (3H each, 2s, MeO-1), 3.3—3.6 (2H, m, HO-2,3), 3.58, 3.68 (3H each, 2d, J_{POMe}=11.1 Hz, POMe), 3.7—4.65 (5H, m, H-2,3,5,5′, NH-4), 4.65—4.80 (1H, m, H-1) 6.8—7.1 (1H, m, TsNH), and 7.20—8.05 (9H, m, C_6H_4-S, C_6H_5-P).

Compound **16** (96 mg) was converted into **14** and **15** (84 mg in total, 80%) by the same procedures for **11**.

Methyl 4-Deoxy-4-(dimethoxyphosphinyl)-2,3-*O*-isopropylidene-β-D-ribo- (17), α-L-Lyxo- (18), (4*S*)-4-Hydrazino-β-D-*erythro*-pentopyranoside (19), and (4*R*)-Epimer (20). A. From 9. Sodium borohydride (140 mg, 3.70 mmol) was added to a soln of **9** (514 mg, 1.07 mmol) in dry THF (15 cm^3) at 0 °C. The mixture was stirred at 25 °C for 12 h. After evaporation of the solvent in vacuo, the residue was diluted with $CHCl_3$, and the ppt was filtered off through activated carbon. The filtrate was washed twice with water, dried (Na_2SO_4), and evapotated in vacuo. The residue was chromatographed on a silica-gel column with AcOEt as an eluant, giving **17—19**.

17: Colorless syrup (153 mg, 48%); R_f=0.35 (*A*); ^{1}H NMR δ=1.36, 1.51 (3H each, 2s, CMe_2), 2.72 (1H, dddd, $J_{4,P}$=23.8, $J_{4,5a}$=11.8, $J_{4,5e}$=5.5, $J_{3,4}$=3.0 Hz, H-4), 3.44 (1H, s, MeO-1), 3.72, 3.75 [3H each, 2d, J_{POMe}=11.1, 10.8 Hz, $P(OMe)_2$], 3.81 (1H, ddd, $J_{5e,5a}$=11.3, $J_{5a,P}$=4.3 Hz, H-5a), 3.90 (1H, dddd, $J_{5e,P}$=2.2, $J_{3,5e}$=0.8 Hz, H-5e), 3.90 (1H, dd, $J_{2,3}$=6.1, $J_{1,2}$=4.8 Hz, H-2), 4.37 (1H, d, H-1), and 4.60 (1H, ddd, $J_{3,P}$=3.0 Hz, H-3); MS *m/z* 281 ($M-CH_3$; 72), 265 (9), 238 (27), 221 (91), 207 (30), 179 (25), 149 (22), 137 (97), 127 (24), 110 (43), 100 (100), and 85 (39).

Found: *m/z* 281.0764. Calcd for $C_{10}H_{18}O_7P$: $M-CH_3$, 281.0790.

18: Colorless syrup (26.0 mg, 8.2%); R_f=0.38 (*A*); ^{1}H NMR δ=1.35, 1.53 (3H each, 2s, CMe_2), 2.35 (1H, br dtd, $J_{4,P}$=19.3, $J_{4,5a}$=8.9, $J_{3,4}$=8.4, $J_{4,5e}$=5.1 Hz, H-4), 3.40 (1H, s, MeO-1), 3.775, 3.78 [3H each, 2d, J_{POMe}=10.9, 10.8 Hz, $P(OMe)_2$], 3.79, 3.81 (1H each,§ H-5a,5e), 3.97 (1H, dt, $J_{2,3}$=5.0, $J_{1,2}$=1.9, $J_{2,P}$=1.6 Hz, H-2), 4.51 (1H, ddd, $J_{3,P}$=11.4 Hz, H-3), and 4.79 (1H, t, $J_{1,5e}$=2.0 Hz, H-1); MS *m/z* 296 (M^+; 0.5), 281 ($M-CH_3$; 12), 221 (39), 177 (41), 149 (25), 109 (57), 100 (100), and 85 (3).

Found: *m/z* 281.0760. Calcd for $C_{10}H_{18}O_7P$: $M-CH_3$, 281.0790.

19: Colorless needles (42.0 mg, 12%); mp 133—134 °C (from AcOEt–hexane); R_f=0.59 (*A*); ^{1}H NMR δ=1.37, 1.61 (3H each, 2s, Me_2C), 3.41 (3H, s, MeO-1), 3.87, 3.875 [3H each, 2d, J_{POMe}=10.5 Hz, $P(OMe)_2$], 3.65 (1H, dd, $J_{5a,5e}$=12.9, $J_{5a,P}$=12.3 Hz, H-5a), 3.92 (1H, ddd, $J_{5e,P}$=4.5, $J_{1,5e}$=1.0 Hz, H-5e), 3.95 (1H, m, HN-4), 4.05 (1H, ddd, $J_{2,3}$=6.3, $J_{1,2}$=3.0, $J_{2,P}$=1.0 Hz, H-2), 4.63 (1H, dd, $J_{3,P}$=9.3 Hz, H-3), 4.70 (1H, dd, H-1), and 5.98, 6.03 (1H each, 2m, H_2NN-4); MS *m/z* 326 (M^+; 59), 311 (11), 307 (11), 294 (27), 279 (12), 259 (10), 247 (17), 229 (35), 217 (79), 205 (21), 194 (31), 177 (51), 166 (100), 156 (23), 141 (29), 136 (34), 127 (61), 109 (71), 99 (68), and 80 (67).

Found: *m/z* 326.1235. Calcd for $C_{11}H_{23}N_2O_7P$: M, 326.1243.

B. From 10. The same procedures described above for the conversion of **9** were followed. Thus, **10** (160 mg) gave **17** (48.6 mg, 49%), **18** (8.7 mg, 9%), and **20** (7.5 mg, 7%) after purification by column chromatography.

20: Colorless syrup; R_f=0.57 (*A*); ^{1}H NMR δ=1.39, 1.55 (3H each, 2s, CMe_2), 3.52 (3H, s, MeO-1), 3.82, 3.93 [3H each, 2d, J_{POMe}=10.7 Hz, $P(OMe)_2$], 3.97 (1H, ddd, $J_{5a,5e}$=13.3, $J_{5e,P}$=2.2, $J_{3,5e}$=1.6 Hz, H-5e), 3.98 (1H, m, HN-4), 4.03 (1H, dd, $J_{2,3}$=5.5, $J_{1,2}$=4.7 Hz, H-2), 4.15 (1H, ddd, $J_{3,P}$=3.0 Hz, H-3), 4.48 (1H, d, H-1), and 5.47, 6.48 (1H each, 2m, H_2NN-4).

Methyl 4-Deoxy-2,3-*O*-isopropylidene-4-[(*R* and *S*)-(methoxy)phenylphosphinyl]-β-D-ribo- (21a,b), α-L-Lyxo- (22a,b), (4*R* and 4*S*)-4-Hydrazino-β-D-*erythro*-pentopyranosides (23), and (4*R*)-Epimer (23a). A. From 14 and 15. By the use of the same procedures as those for **9**, a 9:1 mixture of **14** and **15** (450 mg, 0.855 mmol) was treated with sodium borohydride (100 mg, 2.64 mmol) at 20 °C for 20 h, giving **21a**, **21b**, **22a,b**, and **23**, after separation by column chromatography.

21a: Colorless prisms (98.2 mg, 34%); R_f=0.34 (*A*); mp

§ Their splitting patterns uncertain because of overlapping with other signals.

126—127 °C (from AcOEt–hexane); ^{1}H NMR δ=1.30, 1.48 (3H each, 2s, CMe_2), 2.73 (1H, dddd, $J_{4,P}$=18.5, $J_{4,5a}$=11.7, $J_{4,5e}$=5.5, $J_{3,4}$=3.0 Hz, H-4), 3.44 (3H, s, MeO-1), 3.73 (3H, d, J_{POMe}=11.1 Hz, POMe), 3.80 (1H, t, $J_{2,3}$=5.9, $J_{1,2}$=5.2 Hz, H-2), 3.91 (1H, ddd, $J_{5e,5a}$=11.3, $J_{5a,P}$=3.8 Hz, H-5a), 3.98 (1H, ddt, $J_{5e,P}$=1.3, $J_{3,5e}$=1.2 Hz, H-5e), 4.30 (1H, dddd, $J_{2,3}$=5.9, $J_{3,P}$=3.9 Hz, H-3), 4.33 (1H, d, H-1), 7.48 [2H, m, Ph(*m*)], 7.57 [1H, m, Ph(*p*)], and 7.79 [2H, m, Ph(*o*)]; MS *m/z* 343 (M+1; 1.2), 327 (42), 311 (11), 284 (29), 225 (17), 195 (27), 183 (98), 173 (42), 155 (100), 141 (30), 128 (31), and 100 (95).

Found: *m/z* 327.0983. Calcd for $C_{15}H_{20}O_6P$: M−CH_3, 327.0997.

21b: Colorless syrup (57.2 mg, 20%); R_f=0.30 (*A*); ^{1}H NMR δ=1.31 (6H, s, CMe_2), 2.80 (1H, dddd, $J_{4,P}$=21.3, $J_{4,5a}$=12.0, $J_{4,5e}$=5.3, $J_{3,4}$=3.0 Hz, H-4), 3.43 (3H, s, MeO-1), 3.71 (3H, d, J_{POMe}=11.2 Hz, POMe), 3.75 (1H, ddd, $J_{5e,5a}$=10.9, $J_{5a,P}$=3.7 Hz, H-5a), 4.00 (1H, ddt, $J_{5e,P}$=1.3, $J_{3,5e}$=1.2 Hz, H-5e), 4.31 (1H, d, H-1), 4.55 (1H, dt, $J_{3,P}$=3.2 Hz, H-3), 7.48 [2H, m, Ph(*m*)], 7.57 [1H, m, Ph(*p*)], and 7.77 [1H, m, Ph(*o*)].

22a,b: Colorless syrup (21.0 mg, 7.2%, an inseparable 2:1 mixture of **22a** and **22b**); R_f=0.40 (*A*); ^{1}H NMR for **22a** δ=1.31, 1.39 (3H each, 2s, CMe_2), 2.43 (1H, dddd, $J_{4,P}$=13.0, $J_{4,5a}$=10.5, $J_{3,4}$=8.6, $J_{4,5e}$=4.4 Hz, H-4), 3.36 (3H, s, MeO-1), 3.61 (1H, dddd, $J_{5e,5a}$=12.1, $J_{5e,P}$=7.9, $J_{1,5e}$=1.5 Hz, H-5e), 3.71 (3H, d, J_{POMe}=11.2 Hz, POMe), 3.77 (1H, ddd, $J_{5a,P}$=3.5 Hz, H-5a), 3.93 (1H, dt, $J_{2,3}$=5.2, $J_{1,2}$=1.9, $J_{2,P}$=1.5 Hz, H-2), 4.65 (1H, ddd, $J_{3,P}$=10.7 Hz, H-3), 4.77 (1H, t, H-1), 7.49 [2H, m, $J_{o,m}$=7.5, $J_{m,p}$=7.3, $J_{P,m}$=3.5 Hz, Ph(*m*)], 7.57 [1H, m, $J_{o,p}$=$J_{P,p}$=1.5 Hz, Ph(*p*)], and 7.79 [2H, m, $J_{P,o}$=11.8 Hz, Ph(*o*)], for **22b** δ=1.23, 1.32 (3H each, 2s, CMe_2), 2.47 (1H, dddd, $J_{4,P}$=13.5, $J_{4,5a}$=10.5, $J_{3,4}$=9.1, $J_{4,5e}$=4.5 Hz, H-4), 3.54 (3H, s, MeO-1), 3.66 (3H, s, J_{POMe}=11.2 Hz, POMe), 3.70, 3.78 (1H each,§ H-5a,5e), 3.85 (1H, dt, $J_{2,3}$=5.2, $J_{1,2}$=1.8, $J_{2,P}$=1.5 Hz, H-2), 4.52 (1H, ddd, $J_{3,P}$=11.6 Hz, H-3), 4.79 (1H, t, $J_{1,5e}$=1.5 Hz, H-1), 7.49 [2H, m, Ph(*m*)], 7.57 [1H, m, Ph(*p*)], and 7.79 [2H, m, Ph(*o*)]; MS *m/z* 342 (M^+; 0.5), 327 (31), 311 (10), 267 (33), 225 (23), 209 (35), 195 (11), 183 (44), 173 (21), 155 (100), 128 (63), and 77 (41).

Found: *m/z* 327.0972. Calcd for $C_{15}H_{20}O_6P$: M−CH_3, 327.0997.

23: Colorless syrup (22.2 mg, 7.0%, a ca. 7:1 mixture of (4*S*) and (4*R*) epimers); R_f=0.55—0.50 (*A*); ^{1}H NMR (60 MHz) δ=1.26, 1.37, 1.43, 1.58 (6H, 4s, CMe_2), 3.35, 3.45, 3.48 (3H, 3s, MeO-3), 3.76, 3.81 (3H, d, J_{POMe}=10.8 Hz, POMe), 3.60—4.20 (3H, m, H-5,5′, NH-4), 4.20—4.95 (3H, m, H-1,2,3), 5.6—6.2 (2H, m, H_2NN-4), and 7.45—8.00 (5H, m, PPh).

B. From 15a. By the same procedures described above, **15a** (60.0 mg) was converted into **21a** (22.2 mg, 57%), **22a** (3.0 mg, 7.7%), and **23a** (2.5 mg, 5.9%).

23a: Colorless prisms, mp 169—170 °C (from AcOEt–hexane); R_f=0.50 (*A*); ^{1}H NMR δ=1.26, 1.28 (3H each, 2s, CMe_2), 3.48 (3H, s, MeO-3), 3.87 (1H, br d, $J_{5e,5a}$=13.3, $J_{5a,P}$=0.5 Hz, H-5a), 3.90 (3H, d, J_{POMe}=10.7 Hz, POMe), 3.93 (1H, ddd, $J_{2,3}$=5.5, $J_{3,P}$=2.9, $J_{3,5e}$=2.0 Hz, H-3), 4.02 (1H, t, $J_{1,2}$=5.8 Hz, H-2), 4.06 (1H, m, NH-4), 4.16 (1H, dt, $J_{5e,P}$=2.0 Hz, H-5e), 4.30 (1H, d, H-1), 5.32 (2H, br s, H_2NN-4), 7.49 [2H, m, $J_{o,m}$=7.8, $J_{m,p}$=7.6, $J_{P,m}$=3.6 Hz, Ph(*m*)], 7.61 [1H, m, $J_{m,p}$=1.5, $J_{P,p}$=1.3 Hz, Ph(*p*)], and 7.82 [2H, m, $J_{P,o}$=11.7 Hz, Ph(*o*)].

Methyl 4-Deoxy-2,3-*O*-isopropylidene-4-phosphino-β-D-ribopyranoside (24). To a soln of **17** (220 mg) in dry benzene (4 cm^3) was added, with stirring, a soln of SDMA[13] (70% in toluene, 0.65 cm^3, 3 equiv) in dry benzene (1 cm^3) in small portions at 5 °C under argon. The stirring was continued at this temp for 1 h. Then, water (0.5 cm^3) was added at 0 °C and the mixture was stirred for 30 min. The ppt was centrifuged and washed with several portions of benzene. The organic layers were combined and evaporated in vacuo, giving **24** as a colorless syrup: R_f=0.68 (*A*); MS *m/z* 221 (M+1; 59), 205 (15), 189 (12), 155 (38), 129 (26), 112 (45), 100 (55), and 43 (100); the specimen was not stable enough for ^{1}H NMR and other spectral measurements.

1,2,3,5-Tetra-*O*-acetyl-4-deoxy-4-[(*R* and *S*)-methoxyphosphinyl]-α,β-D-ribopyranoses (26a—d). The above syrup **24** was immediately dissolved in 2-propanol (2 cm^3) and 0.5 M hydrochloric acid (2 cm^3). The mixture was degassed with argon and then stirred at 90 °C for 1 h. After cooling, the reactant was neutralized by adding enough Amberlite IRA-45. The resin was filtered off and washed with water, and the filtrate was evaporated in vacuo. The residue was dissolved in water (2 cm^3), treated with 30% aq hydrogen peroxide (0.2 cm^3) at room temp for 1 d, and concentrated in vacuo to give crude 4-deoxy-4-(hydroxyphosphinyl)-D-ribofuranoses (**25**) as a colorless syrup: R_f=0.10 (*D*).

Compound **25** was methylated with ethereal diazomethane in 1:1 DMSO–MeOH (4 cm^3) at 0 °C. When the reaction mixture became turbid, it was concentrated in vacuo and repeatedly treated with ethereal diazomethane in the same mixed solvent. The solvent was evaporated in vacuo to give the 4-(methoxyphosphinyl) derivative [R_f=0.73 (*D*)]. This was acetylated with acetic anhydride (1.5 cm^3) in dry pyridine (3 cm^3), giving a mixture of tetraacetates **26a—d**, which were separated by column chromatography with a gradient eluant of 3:1 AcOEt–hexane→AcOEt→19:1 AcOEt–EtOH.

26a (4-[(*R*)-Methoxyphosphinyl]-β-isomer): Colorless syrup (17.8 mg, 6.3% yield from **17**); R_f=0.47 (*A*); ^{1}H NMR, see Table 1; MS *m/z* 380 (M^+; ≃0), 354 (0.6), 338 (2.1), 320 (0.8), 296 (32), 278 (19), 236 (24), 218 (15), 193 (16), 177 (42), 149 (31), 123 (21), and 43 (100).

Found: *m/z* 338.0748. Calcd for $C_{12}H_{19}O_9P$: M−CH_2CO, 338.0767.

26b (4-[(*R*)-*P*]-α-Isomer): Colorless syrup (9.3 mg, 3.3% yield from **17**); R_f=0.42 (*A*); ^{1}H NMR, see Table 1; MS *m/z* 381 (M+1; 3.8), 353 (1.8), 338 (4.3), 321 (1.9), 296 (90), 278 (41), 250 (40), 236 (74), 218 (35), 207 (40), 193 (52), 177 (100), 165 (50), 147 (47), 123 (68), and 43 (100).

Found: *m/z* 381.0952. Calcd for $C_{14}H_{22}O_{10}P$: M+1, 381.0951.

26c (4-[(*S*)-*P*]-β-Isomer): Colorless syrup (7.8 mg, 2.8% yield from **17**); R_f=0.40 (*A*); ^{1}H NMR, see Table 1.

26d (4-[(*S*)-*P*]-α-Isomer): Colorless syrup (4.8 mg, 1.7% yield from **17**); R_f=0.34 (*A*); ^{1}H NMR, see Table 1.

1,2,3,5-Tetra-*O*-acetyl-4-deoxy-4-[(*R* and *S*)-phenylphosphinyl]-α,β-D-ribopyranoses (29a—d). The procedures similar to those for **26** from **17** were employed. Thus, **21** (140 mg, 0.41 mmol) was treated with SDMA (0.25 cm^3, 0.85 mmol) at 5 °C for 1 h, giving phosphine oxide **27** as a colorless syrup: R_f=0.70 (*A*). This was refluxed with 1:1 ethanol–0.5 M HCl (4 cm^3, oxygen-free) for 3 h to afford **28** as colorless syrup: R_f=0.48 (*D*). This was acetylated with

Ac_2O–pyridine to give a mixture of **29a—d**, which were separated by column chromatography.

29a (4-[(*S*)-Phenylphosphinyl]-β-isomer): Colorless syrup (20.3 mg, 12% yield from **21**); R_f=0.41 (*A*); ^{1}H NMR, see Table 1; MS *m/z* 426 (M^+; ≃0), 342 (13), 324 (13), 256 (15), 185 (15), and 81 (100); FAB-MS (thioglycerol matrix, with xenon gas) *m/z* 427 (M+1; 100), 385 (21), 369 (53), 343 (13), 327 (10), 309 (16), 267 (11), 223 (14), and 207 (13).

Found: *m/z* 427.1187. Calcd for $C_{19}H_{24}O_9P$: M+1, 427.1158.

29b (4-[(*S*)-*P*]-α-Isomer): Colorless syrup (7.7 mg, 4.4% yield); R_f=0.36 (*A*); ^{1}H NMR, see Table 1.

29c (4-[(*R*)-*P*]-β-Isomer): Colorless syrup (10.9 mg, 6.3% yield); R_f=0.33 (*A*); ^{1}H NMR, see Table 1; MS, *m/z* 426 (M^+; ≃0), 368 (28), 341 (10), 282 (10), 256 (45), 236 (82), 185 (35), and 81 (100); FAB-MS (thioglycerol matrix, with xenon gas), 427 (M+1; 100), 385 (12), 367 (21), 343 (8), 325 (12), 309 (12), 282 (10), 265 (12), 230 (12), 223 (25), 205 (18), and 185 (46).

Found: *m/z* 427.1158. Calcd for $C_{19}H_{24}O_9P$: M+1, 427.1158.

29d (4-[(*R*)-*P*]-α-Isomer): Colorless syrup (5.0 mg, 2.9% yield); R_f=0.27 (*A*); ^{1}H NMR, see Table 1.

Besides these separated products, an inseparable mixture of unidentified products [R_f=0.35—0.20 (*A*), ca. 2% yield from **21**] was obtained, although they were speculated to be the L-lyxofuranose derivatives.

When a 9:1 mixture of **21** and **22** was subjected to the same procedures described above, **29a—d** were also obtained predominantly in similar yields to those described above.

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