Aminosugars. XXXI. Preparation of Benzyl 2-Acylamino-4-azido-2,4-dideoxy-ribo- and -lyxopyranosides by Inversion of Hydroxyl Group on C-3[1)]

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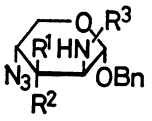
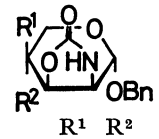
Benzyl 2-acylamino-4-azido-2,4-dideoxypentopyranosides having α-D-*ribo*, β-L-*ribo*, α-D-*lyxo*, and β-L-*lyxo* configurations were derived from the corresponding α-D-*xylo*, β-L-*xylo*, α-D-*arabino*, and β-L-*arabino* isomers, respectively, by inversion of hydroxyl group on C-3. Displacement reaction of sulfonyloxy group with sodium acetate or benzoate in aqueous 2-methoxyethanol or anhydrous *N,N*-dimethylformamide, or oxidation-reduction method *via* ulose derivative was used properly according to the stereochemistry of the starting materials.

In the course of study on the relationship between the configuration and biological activity using diastereomers of an antifungal antibiotic, prumycin: 4-(D-alanyl)-amino-2-amino-2,4-dideoxy-L-arabinose, as model compounds, the *arabino* and *xylo* analogues could be synthesized *via* 2,3-anhydro-4-azido-4-deoxypentopyranosides.[1-3)] In order to complete the synthesis of the remaining diastereomers which have *ribo* and *lyxo* configurations, the inversion of hydroxyl group on C-3 was studied in this paper.

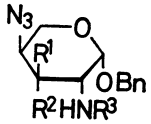
Being used often for the inversion of hydroxyl group, displacement reactions of its sulfonate on the pyranose ring are known to be restrained by the axial substituent on α- or β-carbon with respect to the sulfonyloxy group. Four isomers, namely, α-D-*arabino* (**9**), β-L-*arabino* (**10**), α-D-*xylo* (**11**), and β-L-*xylo* (**12**) diastereomers of benzyl 4-azido-2-benzyloxycarbonylamino-2,4-dideoxy-3-*O*-methylsulfonylpentopyranoside, were prepared from the corresponding ammonolysis products (**1**—**4**) of benzyl 2,3-anhydro-4-azido-4-deoxy-pentopyranosides[1-4)] *via* their *N*-benzyloxycarbonyl derivatives (**5**—**8**). In order to predict the reactivity, the predominant conformers of these 3-*O*-methylsulfonyl derivatives together with the corresponding 3-*O*-acetyl ones (**13**—**16**) were examined by NMR data (Table 1). The conformational equilibria were estimated by the method of averaging of spin coupling[5)] using the values of $J_{4,5a}$ or $J_{4,5e}$† and $J_{2,3}$. Although the standard values for $J_{a,a}$ and $J_{e,e}$ should be determined in each case because of dependency of spin coupling on the substituent groups of the concerned system,[7)] the following values reported for the similar aldopyranoside systems were used: 11.1 and 1.5 Hz for $J_{4a,5a}$ and $J_{4e,5e}$,[8)] and 11.0 and 3.6 Hz for $J_{2a,3a}$ and $J_{2e,3e}$, respectively.[9)] In the cases of α-*arabino* and β-*xylo* isomers whose hydrogens on C-1 and C-2 have *trans* relationship, the ratios of two chair



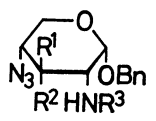
	R¹	R²	R³
1	H	OH	H
5	H	OH	Z
9	H	OMs	Z
13	H	OAc	Z
28	H	OBz	Z
41	H	OH	Ac
42	H	OH	CHO
43	H	OMs	Ac
44	H	OMs	CHO
45	OH	H	Ac
46	OH	H	CHO
50	OAc	H	Ac
51	OAc	H	CHO



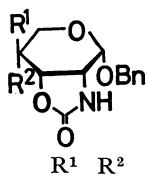
	R¹	R²
18	N_3	H
24	H	N_3



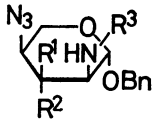
	R¹	R²	R³
2	OH	H	H
6	OH	H	Z
10	OMs	H	Z
14	OAc	H	Z
26	OBz	H	Z
29	OH	H	Ac
30	OH	H	Bz
31	OH	H	CHO
32	OMs	H	Ac
33	OMs	H	Bz
34	OMs	H	CHO
35	H	OH	Ac
36	H	OH	Bz
37	H	OH	CHO
38	H	OAc	Ac
39	H	OAc	Bz
40	H	OAc	CHO



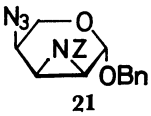
	R¹	R²	R³
3	OH	H	H
7	OH	H	Z
11	OMs	H	Z
15	OAc	H	Z
47	OH	H	Ac
48	OMs	H	Ac
49	H	OH	Ac
52	H	OAc	Ac
54	H	OH	Z
55	H	OAc	Z



	R¹	R²
23	N_3	H
25	H	N_3



	R¹	R²	R³
4	H	OH	H
8	H	OH	Z
12	H	OMs	Z
16	H	OAc	Z
17	OH	H	Z
19	OAc	H	Z
20	OBz	H	Z
22	H	OBz	Z



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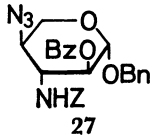

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† The methylene protons on C-5, *i.e.*, H_{5a} and H_{5e} were assigned due to Lemieux's empirical rules[6)] that an axial proton resonates at higher field than an equatrial one.

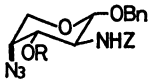
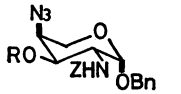
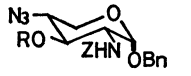
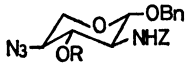
conformers were also calculated from the observed values of $J_{1,2}$ using 7.9[10] and 2.0[9] Hz as standards for $J_{1a,2a}$ and $J_{1e,2e}$, respectively. The results and predominant conformers were shown in Table 2. The ratios obtained from coupling constants between different ring protons gave good agreement with one another indicating that the standard coupling constants used here for the estimation of conformer ratios seem to be also applicable to the here examined system. The conformational equilibria of benzyl 4-azido-2-benzyloxycarbonylamino-

TABLE 1. NMR DATA OF BENZYL 4-AZIDO-2-BENZYLOXYCARBONYLAMINO-2,4-DIDEOXY-3-*O*-METHYLSULFONYLPENTOPYRANOSIDES (**9**—**12**) AND THE CORRESPONDING 3-*O*-ACETYL DERIVATIVES (**13**—**16**) AT 100 MHz IN $CDCl_3$

	Compounds							
	9	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Chemical shifts, δ/ppm								
H-1	4.74 d	4.98 d	4.90 d	4.62 d	4.57 d	4.90 d	4.88 d	4.43 d
H-2	3.74 dd	4.36 dt	4.02 dt	3.50 — 3.80	*ca.* 3.95 —	4.28 dt	3.94 dt	3.79 dd
H-3	*ca.* 5.20 —	4.98 dd	4.62 —		5.24 dd	5.14 dd	*ca.* 5.10 —	4.94 t
H-4	4.10 nm	4.14 nm	3.60 — 3.80m		*ca.* 3.95 —	3.92 m	*ca.* 3.70 —	3.66 dt
H-5[a]	3.60 dd	3.90 dd		3.29 dd	3.59 dd	3.87 dd	3.76 dd	3.24 dd
H-5′[a]	4.05 dd	3.70 dd		4.11 dd	4.04 dd	3.62 dd	3.54 dd	4.07 dd
CH_2 in Bn[b]	4.56, 4.88	4.46, 4.70	4.42, 4.68	4.51, 4.80	4.54, 4.86	4.41, 4.65	4.46, 4.70	4.54, 4.82
CH_2 in Z	5.08 s	5.10[c]	5.09 s	5.07 s	5.09 s	5.06[c]	5.06[c]	5.08 s
NH	5.28	5.21 d	5.26 d	*ca.* 5.18 —	*ca.* 4.85 d	*ca.* 5.04 d	*ca.* 5.10 —	—
Others	2.84(Ms,s)	2.84(Ms,s)	2.94(Ms,s)	2.96(Ms,s)	2.05 (Ac,s)	1.99 (Ac,s)	1.96 (Ac,s)	2.02 (Ac,s)
Coupling constants/Hz								
$J_{1,2}$	7.5	3.6	3.6	7.5	*ca.* 6.2	3.5	3.2	7.5
$J_{2,3}$	—[d]	10.5	10.4	—	9.3	10.5	10.5	9.3
$J_{3,4}$	—	3.5	—	—	3.3	3.5	—	9.0
$J_{4,5}$	1.5	1.5	—	9.4	1.7	2.1	2.0	9.2
$J_{4,5'}$	3.3	2.0	—	4.5	3.5	1.5	10.2	4.5
$J_{5,5'}$	*ca.* 12.5	12.6	—	11.5	12.2	12.4	11.7	11.6
J_{AB}[d]	12.0	11.9	12.0	11.4	12.0	12.0	11.9	12.0
$J_{NH,CH}$	7.8	10.5	9.1	—	—	10.8	—	—

a) H-5 and H-5′ designate pro *R* and pro *S* protons, namely, in $^4C_1$ conformation equatrially and axially oriented protons on C-5, respectively. b) AB quartet with coupling constant J_{AB}. c) Narrow AB quartet. d) Could not be obtained from the spectra. Abbreviation of functional groups: Bn=benzyl, Z=benzyloxycarbonyl, Ac=acetyl and Ms=methylsulfonyl. Observed signal multiplicities: s=singlet, d=doublet, t=triplet, m=multiplet, dd=double doublet, dt=double triplet, nm=narrow multiplet

TABLE 2. RATIOS OF CONFORMERS CALCULATED FROM COUPLING CONSTANTS

Compound	Configuration	Ratios of $^4C_1$ and $^1C_4$ conformers in %				Predominant conformers	
		Calculated from the values of			for methyl tri-*O*-acetylpentopyranosides[a]	R=Ms or Ac	
		$J_{1,2}$	$J_{2,3}$	$J_{4,5}$ or $J_{4,5'}$			
9	α-D-*arabino*	15:85	—[b]	19:81	17:83		$^1C_4$
13	α-D-*arabino*	39:61—20:80[c]	23:77	21:79			
10	β-L-*arabino*	×[d]	93:7	100:0	97:3		$^4C_1$
14	β-L-*arabino*	×	93:7	—			
11	α-D-*xylo*	×	92:8	—	>98:<2		$^4C_1$
15	α-D-*xylo*	×	93:7	91:9			
12	β-L-*xylo*	15:85	—	18:82	19:81		$^1C_4$
16	β-L-*xylo*	15:85	23:77	20:80			

a) see Ref. 11. b) Coupling constants could not be obtained from the spectra. c) Due to overlap of H_1 signal with a part of methylene proton, the exact ratio could not be obtained. d) This method cannot be applied for estimation of conformational equilibria because of *cis*-relationship of H-1 and H-2.

Table 3. Displacement reactions of β-L-*xylo* isomer (**12**)

Run	Reaction conditions					Yield/%						Recovered
	Base	Concentration M	Solvent[a]	Temperature °C	Time h	**17**	**18**	**19**	**20**	**21**	**22**	**12**/%
1	AcONa	0.2	A	95—100	40	44	14	—	—	—	—	28
2	AcONa	0.4	A	95—100	40	52	17	—	—	—	—	19
3	AcONa	0.8	A	95—100	40	62	23	—	—	—	—	0
4	AcONa	0.8	B	95—100	40	61	17	—	—	—	—	0
5	AcONa	1.5	B	95—100	40	60	25	—	—	—	—	0
6	AcONa	0.2	A	115—120	13	44	34	—	—	—	—	10
7	AcONa	0.2	B	115—120	13	37	35	—	—	—	—	14
8	AcONa	0.4	B	115—120	13	45	24	—	—	—	—	7
9	AcONa	0.8	B	115—120	13	41	24	—	—	—	—	10
10	AcONa	1.5	B	115—120	13	38	35	—	—	—	—	0
11	AcONa	0.2	C	95—100	13	—	—	57	—	25	—	0
12	AcONa	0.2	C	115—120	13	—	—	58	—	25	—	0
13	BzONa	0.2[b]	C	95—100	13	—	—	—	69	—	0	0
14	BzONa	0.2[b]	C	115—120	13	—	—	—	68	—	17	0

a) A, 2-methoxyethanol: water=19: 1; B, 2-methoxyethanol: water=4: 1; C, DMF. b) Not fully dissolved.

2,4-dideoxy-3-*O*-methylsulfonylpentopyranosides (**9**—**12**) accord with those of the corresponding 3-*O*-acetyl derivatives (**13**—**16**), and also with those of methyl tri-*O*-acetylpentopyranosides.[11] Among these predominant conformers only that of the β-L-*xylo* isomer (**12**) has no axial substituent on α- and β-carbons as shown in Table 2 (axial substituent with thick line) and seems to be most reactive for displacement reactions. Therefore, some displacement reactions of **12** were examined at first and the results were summarized in Table 3.

The S_N2 type displacements of methylsulfonyloxy group with hydroxyl and acyloxy groups in compound **12** were accomplished in the presence of sodium acetate in 2-methoxyethanol–water and by sodium acetate or benzoate in *N*,*N*-dimethylformamide (DMF), respectively. Under the first conditions, which are used generally for the similar conversion in acylamino sugar derivatives having *trans* vicinal amino alcohol structure in the aid of anchimeric assistance,[12] the desired compound, benzyl 4-azido-2-benzyloxycarbonylamino-2,4-dideoxy-β-L-ribopyranoside (**17**) was obtained as a major product together with benzyl 2-amino-4-azido-2-*N*: 3-*O*-carbonyl-2,4-dideoxy-β-L-ribopyranoside (**18**). Although configuration on C-3 in compound **17** was ascertained by the change of $J_{1,2}$ from the large value (7.5 Hz) in **12** to the small value (2.4 Hz)[3] in predominant $^4C_1$ conformation,[11] the structure was furthermore confirmed unambiguously by the NMR data of its 3-acetate (**19**) (Table 4). On the other hand, absence of benzyloxycarbonyl group ascertained by the NMR and

Table 4. NMR data of compounds **18**—**23** and **25**—**26** at 100 MHz in $CDCl_3$

	Compounds							
	18	**19**	**20**	**21**	**22**	**23**	**25**	**26**
Chemical shifts, δ/ppm								
H-1	4.64 d	4.87 d	4.93 d	5.09 s	4.64 d	4.78 d	4.77 d	5.01 d
H-2	3.82 dd	4.20 m	4.37 m	2.87 d	3.98 ddd	3.94 dd	4.82 dd	*ca.* 4.56 —
H-3	4.93 dd	5.31 t	5.57 t	3.18 dd	5.21 t	4.55 dd	4.85 dd	5.46 dd
H-4	3.94 —	3.92 m	4.10 nm	*ca.* 3.58 nm	3.80 dt	*ca.* 3.92 m	*ca.* 3.65 —	4.06 nm
H-5	—	3.72 dd	3.78 dd	3.91 dd	3.44 dd	3.51 dd	4.03 t	3.72 dd
H-5′	—	3.99 dd	4.10 dd	3.50 dd	4.20 dd	4.13 dd	3.70 —	3.98 dd
CH_2 in Bn	4.54, 4.79	4.49, 4.68	4.52, 4.72	4.55, 4.78	4.56, 4.84	4.56, 4.86	4.50, 4.80	4.48, 4.73
CH_2 in Z		5.10 s	5.10 s	5.16 s	5.03 s			5.00 s
NH	6.12 s	5.88 d	6.02 d		5.32 d	5.40 s	5.55 s	5.08 d
Others		2.02 (Ac, s)						
Coupling constants/Hz								
$J_{1,2}$	3.0	1.4	1.2	<0.5	*ca.* 6.0	3.6	4.2	5.3
$J_{2,3}$	7.6	4.2	4.3	5.8	7.4	7.2	6.0	11.0
$J_{3,4}$	3.3	4.2	4.3	6.2	7.4	4.5	4.5	3.8
$J_{4,5}$	—	1.9	2.3	6.0	7.4	6.0	4.5	2.1
$J_{4,5'}$	—	1.7	1.1	2.6	4.1	4.0	11.7	1.5
$J_{5,5'}$	—	12.0	12.5	13.5	11.9	12.0	11.7	12.5
J_{AB}	11.9	12.0	12.0	11.7	11.9	12.2	12.0	12.0
$J_{NH,CH}$	<0.5	10.1	10.1		*ca.* 9.0	<0.5	<0.5	—

IR spectra of **18** and presence of a typical absorption at 1760 cm^{-1} in the IR spectra assigned to carbonate supported its structure. Moreover the NMR data, especially the large value (7.6 Hz) for $J_{2,3}$, indicated that **18** exists in a boat conformation ($B_{4,1}$).

As shown in Table 3 the higher base concentration, the lower water content of the solvent, and the higher reaction temperature accelerated the formation of both **17** and **18** (Runs 1—10). The last factor, however, favored the formation of **18**, so the ratio of **17** and **18** was changed from 3: 1 at 95—100 °C to nearly 1—2: 1 at 115—120 °C. Although the formation of **18** could not be completely suppressed, among the reaction conditions tested the most suitable combination for preparation of **17** seems to be as follows: concentration of sodium acetate, 0.8—1.5 M; water content of solvent (2-methoxyethanol), 5—20%; reaction temperature, 95—100 °C. All these reactions were carried out in sealed tubes to maintain the constant water content, but for preparative purpose more convinient open air system was examined. It was found that the compound **12** was heated under gentle reflux (in oil bath at 110—115 °C) with sodium acetate (1.5 M) in 20% water containing 2-methoxyethanol to give **17** in unexpectedly good yield (80%) as reported earlier.[3] Considering the azeotropic point (99.5 °C/750 mmHg) of this binary solvent system, these conditions seem to be very similar to the best combination of reaction conditions described above. The difference between closed and open system, however, remains unclear. Furthermore, displacement reaction with sodium acetate or benzoate in DMF gave the corresponding 3-acetate (**19**) or 3-benzoate (**20**) of **17** in good yields (Runs 11—14), while in the former case the aziridine derivative (**21**) in *ca.* 25% yield, and in the latter only at higher temperature the corresponding 3-benzoate (**22**) of **8** were also formed (Run 14). The structure of **19** and **20**, especially the configuration on C-3, was confirmed by the characteristic small coupling constants of all ring protons as shown in Table 4 indicating also that they exist in $^4C_1$ conformation predominantly. The aziridine derivative (**21**) showed no N–H absorption in IR and NMR spectra, and the latter showed typical two protons attached to the aziridine ring at higher magnetic field (δ 2.87 and 3.18) than other pyranoside ring protons. The structure of **22** was also elucidated by NMR spectra in comparison with that of **12** and **16**. The compound **22** may be formed *via* **21** or by the neighboring group participation of urethane carbonyl. The former case may be more reasonable considering relatively weak polarization of benzyloxycarbonyl group. The structure of **22** was also confirmed by its identification with the alternatively prepared 3-benzoate of **8**.

Thus, in the case of *β*-L-*xylo* isomer (**12**) the inversion reactions in the presence of sodium acetate in 80% 2-methoxyethanol and with sodium benzoate in DMF gave good results and then the same reactions of the other three diastereomers of **12** were also examined (Table 5). As expected these isomers resisted the displacement of methylsulfonyloxyl group with both hydroxyl and benzoyloxyl ones. So at the lower temperature (95—100 °C) both reactions did scarcely proceed, and higher temperature (over 120 °C) and higher base concentration promoted decomposition of the starting material and also DMF. In the first reaction the product characterized was only the 2-*N*: 3-*O*-carbonate derivative in each case. The *β*-L-*arabino* isomer (**10**) gave the *β*-L-*lyxo* carbonate (**23**) in 22% yield, while the α-D-*arabino* and α-D-*xylo* isomers (**9** and **11**) gave the corresponding α-D-*lyxo* and α-D-*ribo* carbonate (**24** and **25**) in very low yield. The structure of these carbonate derivatives was easily ascertained by IR absorption of the cyclic carbamate (1755—1760 cm^{-1}) and by NMR signal of the proton attached to the nitrogen, which show a typical broad singlet. The NMR data of **23** and **25** confirmed their structures indicating also the predominance of $^{4,1}B$ conformation. The compound **24** was, however, characterized only by the IR absorption of cyclic carbamate. Moreover, the inversion reaction with benzoate gave no desired product, and those obtained (**26** and **27** from **10**, and **28** from **9**) seem to be derived *via* the corresponding aziridine intermediate as supposed for the formation of **22** from **12**.

As shown in the substitution reaction of **12**, benzyloxycarbonyl group can participate or assist the displacement reaction of the neighboring carbon atom, but such ability is not so strong as those of acetyl, benzoyl and formyl groups.[13] Then, the similar displacement reaction of *N*-acetyl, *N*-benzoyl, and *N*-formyl derivatives was investigated. Because *β*-L-*ribo* and α-D-*ribo* isomers could be prepared by the above mentioned displacement reactions or by oxidation-reduction method as described below, respectively, only *arabino* isomers were examined in detail. The *N*-acetyl (**29**), *N*-benzoyl (**30**), and *N*-formyl (**31**) derivatives of **2** were prepared in the usual manner by treatment with acetic anhydride, benzoyl chloride, or *p*-nitrophenyl formate, respectively. These compounds were converted into the corresponding

Table 5. Displacement reactions of α-D-*arabino* (**9**), *β*-L-*arabino* (**10**) and α-D-*xylo* (**11**) isomers

Run	Starting compound	Reaction conditions					Product (yield)
		Base	Concentration M	Solvent[a]	Temperature °C	Time h	
1	**9**	AcONa	0.4	A, B	110—115	144	**24** (low)
2	**9**	BzONa	0.4[b]	C	110—115	144	**28** (12%)
3	**10**	AcONa	0.4	A	110—115	120	**23** (22%)
4	**10**	BzONa	0.4[b]	C	130	36	**26** (4%), **27** (3%)
5	**11**	AcONA	0.4	A, B	110—115	216	**25** (trace)

a) A, 2-methoxyethanol: water=4: 1; B, 2-methoxyethanol: water=19: 1; C, DMF. b) Not fully dissolved.

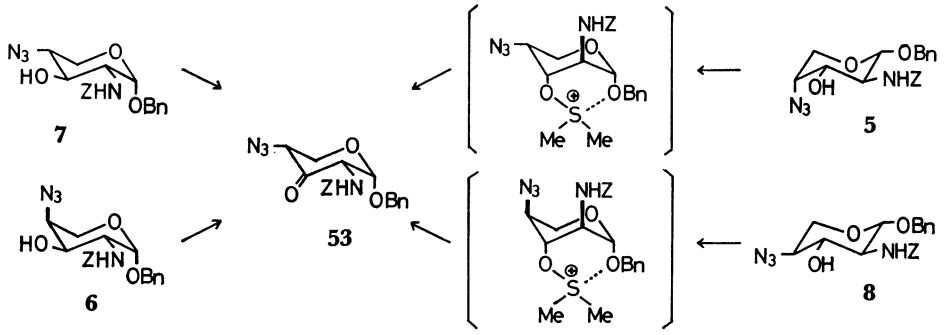
Table 6. NMR data of compounds **28**, **32**—**34**, **36**, and **38**—**40** at 100 MHz in $CDCl_3$

	Compounds							
	28	**32**	**33**	**34**	**36**	**38**	**39**	**40**
Chemical shifts, δ/ppm								
H-1	4.68 d	4.90 d	5.08 d	4.98 d	5.00 d	4.72 d	*ca.* 4.86m	4.75 d
H-2	4.16 dt	4.62 m	4.84 ddd	*ca.* 4.70 m	4.52 m	*ca.* 4.64 —		—
H-3	5.52 dd	5.00 dd	5.18 dd	5.06 dd	3.69 nm	4.90 dd	5.05 dd	4.94 dd
H-4	*ca.* 4.05 —	4.12 nm	4.20 nm	4.20 nm	3.86 nm	3.72 dt	3.80 dt	4.74 ddd
H-5	3.68	3.72 dd	3.78 dd	3.76 dd	3.62 dd	3.42 dd	3.50 dd	3.42 dd
H-5′	*ca.* 4.08 —	3.92 dd	4.00 dd	3.95 dd	4.14 dd	4.10 dd	4.16 dd	4.12 dd
CH_2 in Bn	4.60, 4.91	4.45, 4.68	4.48, 4.71	4.50, 4.74	4.49, 4.76	4.50, 4.82	4.56, 4.86	4.52, 4.82
CH_2 in Z	5.08 s							
NH	5.08 d	5.72 d	6.38 d	6.16 d	6.80 d	5.94 d	6.51 d	6.34 d
Others		1.96 (Ac,s)	3.02 (Ms,s)	3.09 (Ms,s)		1.98 (Ac,s)	2.10 (Ac,s)	2.10 (Ac,s)
		3.08 (Ms,s)		8.21 (HCO,s)		2.10 (Ac,s)		
Coupling constants/Hz								
$J_{1,2}$	6.0	3.3	3.5	2.7	3.3	3.0	—	3.0
$J_{2,3}$	8.7	10.7	10.5	10.8	2.7	3.8	3.8	3.8
$J_{3,4}$	2.7	3.4	3.5	3.4	*ca.* 4.2	6.0	6.0	6.8
$J_{4,5}$	<0.5	2.2	2.0	1.6	3.0	5.3	5.4	6.0
$J_{4,5'}$	—	1.7	1.5	1.2	3.0	3.3	3.2	3.0
$J_{5,5'}$	10.4	12.3	12.0	12.0	13.5	12.2	12.0	12.0
J_{AB}	12.0	11.6	11.7	11.7	12.0	12.3	12.0	12.0
$J_{NH,CH}$	9.0	9.0	9.0	9.0	9.0	8.3	8.4	8.7

3-*O*-methylsulfonyl derivatives (**32**, **33**, and **34**) in high yields. The displacement reactions of **32**, **33**, and **34** using sodium acetate in 20% water-containing 2-methoxyethanol at 115 °C gave benzyl 2-acylamino-4-azido-2,4-dideoxy-β-L-lyxopyranosides; *N*-acetyl derivative (**35**) in quantitative yield, while, *N*-benzoyl one (**36**) in 60%, and *N*-formyl one (**37**) in 70—80% yield, respectively. The structure of these three compounds were ascertained by the NMR spectra of themselves and their 3-acetates (**38**, **39**, and **40**) as shown in Table 6. The coupling constants of ring protons supported the *β-lyxo* configuration and indicated the existence of nearly equal $^4C_1$ and $^1C_4$ conformers, which was deduced from the values of $J_{3,4}$ and $J_{4,5}$. In the case of *N*-benzoyl derivative an unidentified by-product was also obtained in 12% yield, which is deduced to be 2,3-oxazoline derivative having β-L-*lyxo* configuration by spectral data given in the Experimental. As *N*-acetyl and *N*-formyl derivative gave satisfactory results in the case of α-D-*arabino* isomer, only *N*-acetyl (**41**) and *N*-formyl (**42**) derivative of **1** were prepared. Although **41** could be converted into the corresponding 3-*O*-methylsulfonyl derivative (**43**) in high yield, the same conversion of **42** gave **44** in slightly lower yield (60%). Then, similar displacement reaction of *N*-acetyl derivative (**43**) in the presence of sodium acetate as described above gave the α-D-*lyxo* isomer (**45**) in quantitative yield, but the corresponding *N*-formyl derivative (**44**) did inversion product (**46**) in 54% yield. The slightly poor results of *N*-formyl derivative both in the 3-*O*-methylsulfonylation and the inversion reaction may be due to the fact that formyl group is not perfectly stable under these reaction conditions. Furthermore, *N*-acetyl derivative (**47**) of the α-D-*xylo* isomer (**3**) was converted into the corresponding α-D-*ribo* isomer (**49**) *via* the 3-methanesulfonate (**48**) in the same manner. The structures of these inversion reaction products (**45**, **46**, and **49**) were also elucidated by NMR data, especially by coupling constants of ring protons of the corresponding 3-acetates (**50**, **51**, and **52**, respectively).

On the other hand, the inversion of hydroxyl group *via* ulose derivative is also used widely for the synthetic purpose.[14] Then, all isomers (**1**—**4**) were subjected to oxidation with dimethyl sulfoxide–trifluoroacetic anhydride (DMSO–TFAA), which was applied recently to preparation of ulose by us.[15] To our surprise, all isomers gave only one ulose, benzyl 4-azido-2-benzyloxycarbonylamino-2,4-dideoxy-α-D-*erythro*-pentopyranosid-3-ulose (**53**), preferrentially in 80—85% yields. The IR spectrum of **53** shows a new absorption 1740 cm^{-1} due to carbonyl group and the signal of H-2 proton appears as a quartet indicating the proton has no vicinal one other than H-1 and NH. The structure of **53** was further ascertanied by conversion into the α-D-*ribo* derivative by reduction as described below. Thus, except the α-D-*xylo* isomer (**7**) the configuration of at least one substituent on C-2 and C-4 was inverted in the oxidation reaction. As the inversion of the axially oriented group adjacent to carbonyl group was observed often in DMSO oxidation,[16] the case of β-L-*arabino* isomer (**6**) could be explained in the same category. On the other hand, in the cases of α-D-*arabino* (**5**) and β-L-*xylo* (**8**) isomers the change of conformation from $^1C_4$ to $^4C_1$ at the intermediate stage of the reaction should occur, because the inverted groups have equatorial orientations originally. Such conformational change may be caused by the electrostatic attraction between the intermediate sulfonium ion and the lone pair of oxygen at C-1 as shown in Scheme 1.

Then, the reduction of **53** with sodium borohydride



Scheme 1.

in methanol gave stereoselectively the corresponding α-D-*ribo* isomer (**54**) in high yield. The structure of **54** was confirmed by NMR data of its 3-acetate (**55**), which show typical coupling constants of ring protons for α-ribopyranosides.

In conclusion, the four isomers of benzyl 4-azido-2-acylamino-2,4-dideoxypentopyranosides having *ribo* and *lyxo* configurations were prepared from the corresponding *xylo* and *arabino* isomers, and the following facts must be useful. Inversion of hydroxyl group by nucleophilic substitution of its sulfonate with sodium carboxylate can be applied only to β-*xylo* isomer which have no axial substituent in its predominant conformer. On the other hand, inversion using the corresponding 2-acetylamino derivative in the aid of anchimeric assistance can be applied surely to all *xylo* and *arabino* isomers. Furthermore, DMSO oxidation of all four *xylo* and *arabino* isomers followed by sodium borohydride reduction gave α-*ribo* isomer selectively in good yields, respectively.

Experimental

General Methods. Melting points were determined with a Mel-Temp melting point apparatus and not corrected. Optical rotations were measured in chloroform at *c* 1.0, unless otherwise stated, using a 0.5-dm tube with Carl Zeiss LEP-Al or JASCO DIP-4 polarimeter. IR spectra were recorded with a Hitachi EPI-G2 grating spectrometer. NMR spectra were recorded with a JEOL JNM PS-100 spectometer in chloroform-*d* containing tetramethylsilane as the internal reference. Chemical shifts and coupling constants are recorded in δ and Hz units, and IR frequencies in cm^{-1}. Evaporations were conducted under diminished pressure. The products were recrystallized from ethanol unless otherwise stated.

Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxypentopyranosides (5, 6, 7, and 8). To a solution of benzyl 2-amino-4-azido-2,4-dideoxy-pentopyranoside (10 mmol) and sodium hydrogencarbonate (20 mmol) in 1:1 dioxane–water (50 ml) was added benzyloxycarbonyl chloride (13 mmol) dropwise with vigorous stirring at room temperature and stirring was continued overnight. The crystals separated during the reaction was filtered and recrystallized from ethanol to give pure *N*-benzyloxycarbonyl derivative in *ca.* 80% yield. The filtrate was evaporated to give a crystalline residue, which was extracted with chloroform. The extract was washed with water, dried, and evaporated to give a further crop of the product. The combined yield of the product was almost quantitative. In the cases of α-D- and β-L-*arabino* isomers the ammonolysis mixture which contain 2- and 3-amino derivatives in the ratio of 3:2[4] was directly subject to this reaction because of difficulty of separation of each component on a column in large scale, and the 2-benzyloxycarbonylamino derivative was obtained in *ca.* 40% yield by fractional crystallization from ethanol.

Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-α-D-arabinopyranoside (5): Mp 188—190 °C; $[\alpha]_D$ +24.2° (*c* 1.9 $CHCl_3$), +31.5° (*c* 0.7 MeOH): The reported value of −110° for the enantiomer of **5**[17] seems to be incorrect; IR (KBr): 3420 and 3320 (OH and NH), 2100 (N_3), 1690 and 1540 (urethane). Found: C, 60.12; H, 5.59; N, 14.02%. Calcd for $C_{20}H_{22}N_4O_5$: C, 60.29; H, 5.57; N, 14.06%. Acetylation of **5** with acetic anhydride in pyridine gave its 3-acetate (**13**) in quantitative yield. Mp 183—184 °C; $[\alpha]_D$ +18.8°; IR (KBr): 3300 (NH), 2100 (N_3), 1738 (ester), 1685 and 1540 (urethane), 730 and 698 (phenyl). Found: C, 59.66; H, 5.57; N, 12.83%. Calcd for $C_{22}H_{24}N_4O_6$: C, 59.99; H, 5.49; N, 12.72%.

Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-β-L-arabinopyranoside (6): Mp 159—160 °C; $[\alpha]_D$ +143°; IR (KBr): 3315 (OH and NH), 2120 (N_3), 1690 and 1530 (urethane). Found: C, 60.45; H, 5.61; N, 13.99%. Calcd for $C_{20}H_{22}N_4O_5$: C, 60.29; H, 5.57; N, 14.06%. Acetylation of **6** in a usual manner gave its 3-acetate (**14**) in good yield. Mp 129—130 °C; $[\alpha]_D$ +134.0°; IR (KBr): 3340 (NH), 2120 (N_3), 1735 (ester), 1685 and 1515 (urethane), 735 and 703 (phenyl). Found: C, 60.09; H, 5.43; N, 12.63%. Calcd for $C_{22}H_{24}N_4O_6$: C,59.99; H, 5.49; N, 12.72%.

Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideozy-α-D-xylopyranoside (7): Mp 114—115 °C; $[\alpha]_D$ +123.9°; IR (KBr): 3325 (OH and NH), 2100 (N_3), 1690 and 1530 (urethane), 733 and 695 (phenyl). Found: C, 60.00; H, 5.52; N, 13.87%. Calcd for $C_{20}H_{22}N_4O_5$: C, 60.29; H, 5.57; N, 14.06%. Acetylation of **7** in a usual manner gave its 3-acetate (**15**) in good yield. Mp 106—107 °C; $[\alpha]_D$ +157.3°; IR (KBr): 3400 (NH), 2098 (N_3), 1745 (ester), 1718 and 1502 (urethane), 735 and 690 (phenyl). Found: C, 59.90; H, 5.51; N, 12.24%. Calcd for $C_{22}H_{24}N_4O_6$: C, 59.99; H, 5.49; N, 12.72%.

Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-β-L-xylopyranoside (8) was already reported.[3] Acetylation of **8** in a usual manner gave its 3-acetate (**16**) in good yield. Mp 134—137 °C; $[\alpha]_D$ +13.6°; IR (KBr): 3305 (NH), 2110 (N_3), 1750 (ester), 1698 and 1540 (urethane), 738 and 695 (phenyl). Found: C, 60.10; H, 5.49; N, 12.76%. Calcd for $C_{22}H_{24}N_4O_6$: C, 59.99; H, 5.49; N, 12.72%.

Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-3-O-methylsulfonylpentopyranosides (9, 10, 11, and 12). To a solution of the compound **5**, **6**, **7**, or **8** (2 mmol) in pyridine (5 ml) was added methylsulfonyl chloride (3 mmol) dropwise with stirring at 0 °C. Stirring was continued overnight at room temperature. The solution was poured into ice–water with

stirring. After 3 h, a crystalline precipitate separated was collected by filtration and recrystallized from ethanol to give the corresponding 3-*O*-methylsulfonyl derivative in 90—95% yield.

*Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-3-O-methylsulfonyl-α-D-arabinopyranoside (**9**)*: Mp 160—162 °C; $[\alpha]_D$ +3.5°; IR (KBr): 3320 (NH), 2100 (N_3), 1690 and 1535 (urethane), 1335 (SO_2), 733 and 695 (phenyl). Found: C, 53.33; H, 5.20; N, 11.41; S, 6.68%. Calcd for $C_{21}H_{24}N_4O_7S$: C, 52.94; H, 5.08; N, 11.76; S, 6.72%.

*Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-3-O-methylsulfonyl-β-L-arabinopyranoside (**10**)*: Mp 139—140 °C; $[\alpha]_D$ +137.0°; IR (KBr): 3360 (NH), 2130 (N_3), 1690 and 1535 (urethane), 1365 (SO_2), 740 and 700 (phenyl). Found: C, 52.50; H, 5.07; N, 11.82; S, 6.96%. Calcd for $C_{21}H_{24}N_4O_7S$: C, 52.94; H, 5.08; N, 11.76; S, 6.72%.

*Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-3-O-methylsulfonyl-α-D-xylopyranoside (**11**)*: Syrup; $[\alpha]_D$ +124.5°; IR (NaCl): 3375 (NH), 2110 (N_3), 1695 and 1523 (urethane), 1345 and 1175 (SO_2), 740 and 700 (phenyl). Found: C, 53.25; H, 5.31; N, 11.32%. Calcd for $C_{21}H_{24}N_4O_7S$: C, 52.94; H, 5.08; N, 11.76%.

*Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-3-O-methylsulfonyl-β-L-xylopyranoside (**12**)* was reported already.[3]

General Methods for Inversion Reaction with Sodium Acetate or Benzoate. All inversion reactions were carried out in sealed tubes or tightly stoppered test tubes at a temperature between 95 and 140 °C using 2-methoxyethanol–water or DMF as solvent.

Inversion Reaction with Sodium Acetate in 2-Methoxyethanol–Water: The starting 3-metanesulfonate (50 mg, 0.1 mmol) and sodium acetate (50—380 mg, 0.55—4 mmol) were dissolved or suspended in 2-methoxyethanol–water (19: 1 or 4: 1, 3 ml) and heated. Undissolved material went into the solution during the reaction. Then, the reaction solution was evaporated directly to give a residue, which was extracted with acetone. The extract was concentrated to a small volume, and subjected to preparative TLC on silica gel.

Inversion Reaction with Sodium Acetate or Benzoate in DMF: A suspension of the 3-methanesulfonate (50 ml, 0.1 mmol) and sodium acetate (41 mg, 0.5 mmol) or benzoate (85 mg, 0.5 mmol) in DMF (3 ml) was heated. Sodium benzoate did not dissolved completely even at higher temperature, and formation of resin-like material was observed by long time heating at higher than 130 °C. Work-up was done in the same manner as described above.

*Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-β-L-ribopyranoside (**17**) and Benzyl 2-Amino-4-azido-2-*N*: 3-O-carbonyl-2,4-dideoxy-β-L-ribopyranoside (**18**)*. A mixture of **12** (95 mg, 0.2 mmol) and sodium acetate (656 mg, 80 mmol) in 80% 2-methoxyethanol (6 ml) was heated at 95—100 °C for 40 h. A mixture of products obtained as described above was separated on a silica gel TLC using 19: 1 benzene–methanol as a solvent to give **17** (51 mg) and **18** (14 mg), in 60 and 20% yields, respectively.

17: Syrup. The optical rotation, IR, and NMR spectra were identical with those reported previously.[3]

18: Syrup; $[\alpha]_D$ +71.0°; IR (NaCl): 3300 (NH), 2090 (N_3), 1760 (cyclic urethane), 735 and 695 (phenyl). Found: C, 53.44; H, 5.04; N, 18.93%. Calcd for $C_{13}H_{14}N_4O_4$: C, 53.79; H, 4.86; N, 19.30%.

*Benzyl 3-O-Acetyl-4-azido-2-benzyloxycarbonylamino-2,4-dideoxy-β-L-ribopyranoside (**19**) and Benzyl 4-Azido-N-benzyloxycarbonyl-2,3-epimino-2,3,4-trideoxy-β-L-ribopyranoside (**21**)*. A mixture of **12** (50 mg, 0.1 mmol) and sodium acetate (54 mg, 0.65 mmol) in DMF (3 ml) was heated at 115—120 °C for 13 h. The similar work-up mentioned above gave **19** (27 mg) and **21** (10 mg) in 58 and 25% yields, respectively.

19: Syrup; $[\alpha]_D$ +76.6°; IR (NaCl): 3410 (NH), 2100 (N_3), 1745 (ester), 1720 and 1500 (urethane), 740 and 700 (phenyl). Found: C, 59.95; H, 5.48; N, 12.85%. Calcd for $C_{22}H_{24}N_4O_6$: C, 59.99; H, 5.49; N, 12.72%.

21: Syrup; The structure was ascertained only by NMR data (Table 4).

*Benzyl 4-Azido-3-O-benzoyl-2-benzyloxycarbonylamino-2,4-dideoxy-β-L-ribopyranoside (**20**) and -β-L-xylopyranoside (**22**)*. A suspension of **12** (50 mg, 0.10 mmol) and sodium benzoate (85 mg, 0.5 mmol) in DMF (3 ml) was heated at 115—120 °C for 13 h. The similar work-up mentioned above gave **20** (39 mg, 68%) and **22** (10 mg, 17%). At lower reaction temperature (95—100 °C) only **16** was obtained in 69% yield.

20: Mp 88—90 °C; $[\alpha]_D$ +28.2°; IR (KBr): 3410 (NH), 2100 (N_3), 1720 (ester), *ca.* 1700 and 1500 (urethane), *ca.* 740 and 705 (phenyl). Found: C, 64.47; H, 5.26; N, 11.26%. Calcd for $C_{27}H_{26}N_4O_6$: C, 64.53; H, 5.22; N, 11.15%.

22: Mp 122.0—123.5 °C; $[\alpha]_D$ +25.5°; IR (KBr): 3330 (NH), 2110 (N_3), 1720 (ester), 1700, and 1520 (urethane), 710 and 698 (phenyl).

*Benzyl 2-Amino-4-azido-2-N: 3-O-carbonyl-2,4-dideoxy-β-L-lyxopyranoside (**23**)*. A solution of **10** (128 mg, 0.26 mmol) and sodium acetate (170 mg) in 80% aqueous 2-methoxyethanol was heated at 110—115 °C and evaporated to dryness. The residue was shaken with chloroform and water. The chloroform layer was evaporated to give a dark brown syrup. The syrup was separated on preparative TLC with 8: 1 benzene–acetone to give **23** (18 mg, 23%). Mp 102—104 °C; $[\alpha]_D$ +126.0°; IR (KBr): 3300 (NH), 2090 (N_3), 1760 (cyclic urethane), 735 and 695 (phenyl). Found: C, 52.19; H, 4.88; N, 18.85%. Calcd for $C_{13}H_{14}N_4O_4 \cdot 1/2H_2O$: C, 52.17; H, 5.02; N, 18.71%.

*Benzyl 2-Amino-4-azido-2-N: 3-O-carbonyl-2,4-dideoxy-α-D-ribopyranoside (**25**)*. Similarly, **25** was obtained from **11** in 17% yield. Mp 118—120 °C; $[\alpha]_D$ +130.0°; IR (KBr): 3260 (NH), 2100 (N_3), 1755 (cyclic urethane), 735 and 695 (phenyl). Found: C, 53.34; H, 4.88; N, 18.96%. Calcd for $C_{13}H_{14}N_4O_4$: C, 53.79; H, 4.86; N, 19.30%.

*Reaction of **10** with Sodium Benzoate.* A mixture of **10** (393 mg, 0.77 mmol) and sodium benzoate (540 mg) in DMF (20 ml) was heated at 140 °C for 17 h to give many products on TLC. Sodium benzoate did not dissolved completely during the reaction. The solution turned black was evaporated. The residue was shaken with chloroform and water. The chloroform layer was evaporated to give a black syrup. The syrup was separated on preparartive TLC with 8: 1 benzene–acetone to give benzyl 4-azido-2-benzyloxycarbonylamino-3-*O*-benzoyl-2,4-dideoxy-β-L-arabinopyranoside (**26**) and benzyl 4-azido-3-benzyloxycarbonylamino-2-*O*-benzoyl-3,4-dideoxy-β-L-xylopyranoside (**27**) in 3.8 and 3.0% yields, respectively. Besides **26** and **27**, benzyl 4-azido-3-*O*-benzoyl-2,4-dideoxy-2-(3,3-dimethylureido)-β-L-arabinopyranoside could be also obtained in 7.8% yield, but its structure was deduced only by the following spectral data. IR (NaCl): 3450 and 3470 (NH), 2120 (N_3), 1725 (ester), and 1660 and 1525 (amide), 710 (phenyl); NMR: 5.07 (H_1: d, $J_{1,2}$=3.0), 5.60 (H_3: dd, $J_{2,3}$=10.5, $J_{3,4}$=3.6), 5.12 (H_4: broad s), 4.06 (H_5: dd, $J_{4,5'}$=1.5, $J_{5,5'}$=12.8), 3.80 ($H_{5'}$: dd, $J_{4,5'}$=1.5), 2.74 (6H, *N*-CH_3: s).

26: Mp 85—87 °C; $[\alpha]_D$ +114.0°; IR (KBr): 3320 (NH), 2100 (N_3), 1715 (ester), 1685 and 1515 (urethane), 735, 705, and 695 (phenyl). Found: C, 64.83; H, 5.21; N, 11.30%. Calcd for $C_{27}H_{26}N_4O_6$: C, 64.53; H, 5.22; N, 11.15%.

27: Mp 142—144 °C; $[\alpha]_D$ +3.9°; IR (KBr): 3320 (NH), 2125 (N_3), 1715 (ester), 1695 and 1540 (urethane), 730, 700, and 690 (phenyl). Found: C, 64.60; H, 5.15; N, 10.96%.

Calcd for $C_{27}H_{26}N_4O_6$: C, 64.53; H, 5.22; N, 11.15%.

Reaction of **9** *with Sodium Benzoate.* A mixture of **9** (231 mg, 0.45 mmol) and sodium benzoate (278 mg) in DMF (10 ml) was heated at 110—115 °C for 5 days. The mixture of products obtained by the same work-up as described in the reaction of **10** was separated on preparative TLC with 7: 1 benzene–methanol to give benzyl 4-azido-3-*O*-benzoyl-2-benzyloxycarbonylamino-2,4-dideoxy-α-D-arabinopyranoside (**28**, 27 mg) in 13% yield. Mp 77—79 °C; $[\alpha]_D$ +29.9°; IR (KBr): 3325 (NH), 2105 (N_3), 1720 (ester), 1695 and 1530 (urethane), 735, 715 and 695 (phenyl). Found: C, 64.18; H, 5.36; N, 10.80%. Calcd for $C_{27}H_{26}N_4O_6$: C, 64.53; H, 5.22; N, 11.15%.

General Method for N-*Acetylation.* To a solution of 2-amino derivative (**2**, **1**, or **3**, 10 mmol) in ethanol (30 ml) was added acetic anhydride (15 mmol) dropwise with stirring at room temperature. After 30 min, water was added to a suspension of crystallized product, and this suspension was evaporated directly to give a crystalline residue, which was recrystallized from ethanol to give the corresponding *N*-acetyl derivative in 85—90%.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-β-*L*-arabinopyranoside (**29**)*: As in the preparation of **6** the ammonolysis mixture of benzyl 4-azido-2,3-anhydro-β-L-ribopyranoside was used, and **29** was obtained in *ca.* 40% yield by fractional crystallization from ethanol. Mp 178—180 °C; $[\alpha]_D$ +217.9° (MeOH); IR (KBr): 3455 and 3395 (OH and NH), 2130 (N_3), 1655 and 1550 (amide), 735 and 695 (phenyl). Found: C, 54.95; H, 5.83; N, 18.35%. Calcd for $C_{14}H_{18}N_4O_4$: C, 54.89; H, 5.92; N, 18.29%.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-α-*D*-arabinopyranoside (**41**)*: Mp 208—210 °C; $[\alpha]_D$ +47.2° (MeOH); IR (KBr): 3280 (OH and NH), 2110 (N_3), 1650 and 1550 (amide), 730 and 692 (phenyl). Found: C, 54.95; H, 5.84; N, 18.25%. Calcd for $C_{14}H_{18}N_4O_4$: C, 54.89; H, 5.92; N, 18.29%.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-α-*D*-xylopyranoside (**47**)*: Mp 160—161 °C; $[\alpha]_D$ +210.9° (MeOH); IR (KBr): 3500 and 3280 (OH and NH), 2105 (N_3), 1630 and 1525 (amide), 735 and 695 (phenyl). Found: C, 55.15; H, 5.95; N, 18.52%. Calcd for $C_{14}H_{18}N_4O_4$: C, 54.89; H, 5.92; N, 18.29%.

*Benzyl 4-Azido-2-benzoylamino-2,4-dideoxy-β-*L*-arabinopyranoside (**30**).* To a solution of **2** (2.0 g, 6.7 mmol) in 1: 1 dioxane–water (40 ml) was added potassium hydroxide (0.38 g, 6.7 mmol) and benzoyl chloride (1.54 g, 11 mmol) with stirring in an ice–water bath. After 3 h the solution was poured into ice–water. The crystalls separated were collected by filtration, washed with 1 M sodium hydroxide and recrystallized from ethanol to give **30** in a quantitative yield. Mp 167—170 °C; $[\alpha]_D$ +140.0° ($CHCl_3$); IR (KBr): 3275 (OH and NH), 2105 (N_3), 1630 and 1523 (amide), 732 and 692 (phenyl). Found: C, 62.24; H, 5.17; N, 14.91%. Calcd for $C_{19}H_{20}N_4O_4$: C, 61.94; H, 5.47; N, 15.21%.

*Benzyl 4-Azido-2,4-dideoxy-2-formylamino-β-*L*-arabinopyranoside (**31**) and -α-*D*-arabinopyranoside (**42**).* To a solution of 2-amino derivative (**2** or **1**, 1 mmol) in tetrahydrofuran (10 ml) was added a solution of *p*-nitrophenyl formate (2 mmol) in tetrahydrofuran (5 ml) dropwise with stirring at 0 °C. After standing overnight at room temperature, the solution was evaporated to give a crystalline residue, which was purified on a column of silica gel with 15: 1 benzene–ethanol to give the corresponding 2-formylamino derivative in good yield.

31: Mp 166—167 °C; $[\alpha]_D$ +205.0° (MeOH); IR (KBr): 3295 (OH and NH), 2140 (N_3), 1655 and 1545 (amide), 740 and 700 (phenyl). Found: C, 53.13; H, 5.54; N, 19.00%. Calcd for $C_{13}H_{16}N_4O_4$: C, 53.42; H, 5.52; N, 19.17%.

42: Mp 194—195 °C; $[\alpha]_D$ +44.7° (MeOH); IR (KBr): 3290 (OH and NH), 2110 (N_3), 1645 and 1530 (amide), 730 and 705 (phenyl). Found: C, 53.67; H, 5.53; N, 19.31%. Calcd for $C_{13}H_{16}N_4O_4$: C, 53.42; H, 5.52; N, 19.17%.

*Benzyl 2-Acetylamino-(or 2-Formylamino)-4-azido-2,4-dideoxy-3-O-methylsulfonylpentopyranosides (**32**, **34**, **43**, **44**, and **48**).* To a solution of the compound to be methylsulfonylated (**29**, **31**, **41**, **42** or **47**) (2 mmol) in pyridine (15 ml) was added methanesulfonyl chloride (3 mmol) dropwise with stirring at 0 °C. After stirring overnight at room temperature, water was added to the solution, and the solution was evaporated directly to give black syrupy residue. The residue was fractionated on a silica-gel column using 5: 1 benzene–acetone as eluant to give the corresponding 3-*O*-methylsulfonyl derivative in 80%—quantitative yield.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-3-*O*-methylsulfonyl-β-*L*-arabinopyranoside (**32**)*: Mp 137—138 °C; $[\alpha]_D$ +213.8° (*c* 1.0, MeOH); IR (KBr): 3305 (NH), 2120 (N_3), 1645 and 1530 (amide), 1365 and 1180 (SO_2), 735 and 698 (phenyl). Found: C, 46.58; H, 5.20; N, 14.95; S, 8.52%. Calcd for $C_{15}H_{20}N_4O_6S$: C, 46.87; H, 5.25; N, 14.58; S, 8.33%.

*Benzyl 4-Azido-2,4-dideoxy-2-formylamino-3-*O*-methylsulfonyl-β-*L*-arabinopyranoside (**34**)*: Syrup; IR (KBr): 3375 (NH), 2110 (N_3), 1665 (amide), 1345 (SO_2), 700 (phenyl). Beside spectral data (NMR data in Table 6), other characterization could not be done because of its unstability.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-3-*O*-methylsulfonyl-α-*D*-arabinopyranoside (**43**)*: Mp 148—150 °C; $[\alpha]_D$ +19.2° (*c* 1.0, MeOH); IR (KBr): 3250 (NH), 2100 (N_3), 1645 and 1545 (amide), 1360 and 1178 (SO_2), 750 and 695 (phenyl). Found: C, 47.13; H, 5.24; N, 14.87; S, 8.53%. Calcd for $C_{15}H_{20}N_4O_6S$: C, 46.87; H, 5.25; N, 14.58; S, 8.33%.

*Benzyl 4-Azido-2,4-dideoxy-2-formylamino-3-*O*-methylsulfonyl-α-*D*-arabinopyranoside (**44**)*: Mp 162—163 °C; $[\alpha]_D$ +15.4° (MeOH); IR (KBr): 3300 (NH), 2120 (N_3), 1662 and 1535 (amide), 1338 and 1175 (SO_2), 725 and 700 (phenyl). Found: C, 45.25; H, 4.92; N, 15.10; S, 8.53%. Calcd for $C_{14}H_{18}N_4O_6S$: C, 45.40; H, 4.90; N, 15.13; S, 8.45%.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-3-*O*-methylsulfonyl-α-*D*-xylopyranoside (**48**)*: Mp 115—117 °C; $[\alpha]_D$ +141.5° (*c* 1.0, MeOH); IR (KBr): 3275 (NH), 2100 (N_3), 1650 and 1510 (amide), 1345 (SO_2), 722 and 690 (phenyl). Found: C, 46.71; H, 5.15; N, 14.30; S, 8.17%. Calcd for $C_{15}H_{20}N_4O_6S$: C, 46.87; H, 5.25; N, 14.58; S, 8.33%.

*Benzyl 4-Azido-2-benzoylamino-2,4-dideoxy-3-*O*-methylsulfonyl-β-*L*-arabinopyranoside (**33**).* Compound **30** was methylsulfonylated as described in the preparation of **9**—**12** to give **33** in 95% yield. Mp 163—164 °C; $[\alpha]_D$ +150.7°; IR (KBr): 3320 (NH), 2140 (N_3), 1635 and 1530 (amide), 1362 and 1188 (SO_2), 730 and 695 (phenyl). Found: C, 54.03; H, 4.97; N, 12.37; S, 7.00%. Calcd for $C_{20}H_{22}N_4O_6S$: C, 53.81; H, 4.97; N, 12.55; S, 7.17%.

*Inversion Reaction of 2-Acylamino Derivatives (**32**, **33**, **34**, **43**, **44**, and **48**).* A solution of 2-acylamino derivative (1 mmol) and sodium acetate (5 mmol) in 80% 2-methoxyethanol was heated in a sealed tube overnight at 110—115 °C. The solution was evaporated and the residue was purified on a colomn of silica gel to give a product in various yields.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-β-*L*-lyxopyranoside (**35**)*: The inversion reaction of **32** as described above gave **35** in 89% yield. Mp 117—119 °C; $[\alpha]_D$ +116.8° (MeOH); IR (KBr): 3330 (OH and NH), 2110 (N_3), 1650 and 1520 (amide), 740 and 704 (phenyl). Found: C, 55.19; H, 5.95; N, 18.35%. Calcd for $C_{14}H_{18}N_4O_4$: C, 54.89; H, 5.92; N, 18.29%. A usual acetylation of **35** gave the corresponding 3-*O*-acetyl derivative (**38**): Only NMR spectra was taken (Table 6).

*Benzyl 4-Azido-2-benzoylamino-2,4-dideoxy-β-L-lyxopyranoside (**36**).* Similarly, **33** gave **36** in 60% yield. IR (KBr): 3420 (OH and NH), 2090 (N_3), 1630 (amide), 705 (phenyl). Further characterization was done as its 3-*O*-acetyl derivative (**39**): Syrup; $[\alpha]_D$ +62.4°; IR (NaCl): 3440 and 3360 (NH), 2105 (N_3), 1745 (ester), 1660 and 1510 (amide), 710 and 695 (phenyl). Found: C, 61.31; H, 5.48; N, 13.30%. Calcd for $C_{21}H_{22}N_4O_5$: C, 61.45; H, 5.40; N, 13.65%. The by-product obtained in a low yield and supposed to be an oxazoline derivative has the following spectral data. IR (NaCl): 2095 (N_3), 1720, 1640 and 695; NMR: 5.09 (H_1: d, $J_{1,2}$=4.0), 4.50 (H_2: dd, $J_{2,3}$=9.3), 4.70 (H_3: dd, $J_{3,4}$=6.8), 4.28 (H_4: ddd), 3.94 (H_{5a}: dd, $J_{4,5a}$=5.7, $J_{5a,5b}$=11.0), 3.43 (H_{5b}: t, $J_{4,5b}$=10.1), 4.83 and 4.65 (ABq. CH_2 in Bn), 7.26 (broad s, 5H), 7.48 (m, 2H) and 8.02 (m, 2H).

*Benzyl 4-Azido-2,4-dideoxy-2-formylamino-β-L-lyxopyranoside (**37**)*: Similarly, **34** gave **37** in 65% yield. Syrup, $[\alpha]_D$ +72.3° (MeOH); IR (NaCl), 3320 (OH and NH), 2100 (N_3), 1660 (amide), 735 and 695 (phenyl). Found: C, 53.21; H, 5.66; N, 18.81%. Calcd for $C_{13}H_{16}N_4O_4$: C, 53.42; H, 5.52; N, 19.17%. A usual acetylation of **37** gave the corresponding 3-*O*-acetyl derivative (**40**): Mp 99—101 °C; $[\alpha]_D$ +134.3°; IR (KBr): 3415 and 3180 (NH), 2105 (N_3), 1730 (ester), 1645 (amide), 695 (phenyl). Found: C, 53.68; H, 5.44; N, 16.65%. Calcd for $C_{15}H_{18}N_4O_5$: C, 53.88; H, 5.43; N, 16.76%.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-α-D-lyxopyranoside (**45**)*: Similarly, **43** gave **45** in quantitative yield. $[\alpha]_D$ +133.0° (MeOH); IR (KBr): 3325 (OH and NH), 2110 (N_3), 1645 and 1530 (amide), 728 and 700 (phenyl). Found: C, 53.72; H, 6.02; N, 17.74%. Calcd for $C_{14}H_{18}N_4O_4 \cdot 1/2H_2O$: C, 53.50; H, 6.05; N, 17.83%. NMR data of its 3-acetate (**50**): 4.74 (H_1: d, $J_{1,2}$=1.5), 4.65 (H_2: dq, $J_{2,3}$=4.5, $J_{NH,CH}$=9.0) 5.24 (H_3: dd, $J_{3,4}$=9.0)

*Benzyl 4-Azido-2,4-dideoxy-2-formylamino-α-D-lyxopyranoside (**46**)*: Similarly, **44** gave **46** in low yield. Mp 97—98 °C, $[\alpha]_D$ +72.9° (MeOH); IR (KBr): 3455, 3350 (NH and OH), 2080 (N_3), 1648 and 1505 (amide), 740 and 695 (phenyl). Found: C, 53.30; H, 5.83; N, 17.45%. Calcd for $C_{14}H_{18}N_4O_4 \cdot 1/2H_2O$: C, 53.33; H, 6.03; N, 17.78%.

*Benzyl 2-Acetylamino-4-azido-2,4-dideoxy-α-D-ribopyranoside (**49**)*: Similarly, **48** gave **49** in 83% yield. Mp 94—96 °C; $[\alpha]_D$ +72.9° (MeOH); IR (KBr): 3455 and 3350 (OH and NH), 2080 (N_3), 1648 and 1505 (amide), 740 and 695 (phenyl). Found: C, 53.30; H, 5.83; N, 17.45%. Calcd for $C_{14}H_{18}N_4O_4 \cdot 1/2H_2O$: C, 53.33; H, 6.03; N, 17.78%. NMR data of its 3-acetate (**52**): 4.70 (H_1: d, $J_{1,2}$=3.8), 4.39 (H_2: dt, $J_{2,3}$=3.8, $J_{NH,CH}$=9.5), 5.43 (H_3: t, $J_{3,4}$)=3.8).

*Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-α-D-erythro-pentopyranosid-3-ulose (**53**).* Dimethyl sulfoxide (2.65 g,34 mmol) and dichloromethane (5 ml) were put into Erlenmeyer flask with vigorous stirring at −76 °C. To this solution was added trifluoroacetic anhydride (3.56 g, 18 mmol) with vigorous stirring for 5 min at −76 °C and was added a solution of **6** (2.92 g, 6.75 mmol) in dichloromethane (20 ml). After 1 h, to this solution was added triethylamine (3 ml) dropwise. After 10 min, the solution was mixed with chloroform–water, and the chloroform layer was evaporated to give a crystalline, which was recrystallized from ethanol to give **44** in 81.7% yield (2.37 g): Mp 123—125 °C; $[\alpha]_D$ +173.8° ($CHCl_3$); IR (KBr): 3350 (OH and NH), 2100 (N_3), 1740 (ketone), 1720 and 1530 (urethane), 695 (phenyl). Found: C, 60.35; H, 5.13; N, 14.09%. Calcd for $C_{20}H_{20}N_4O_5$: C, 60.60; H, 5.09; N, 14.14%.

The stereoisomers of **6** (**5**, **7**, and **8**) were also oxidized in the same manner as described above to give the same ulose derivative (**53**) in 80—85% yields.

*Benzyl 4-Azido-2-benzyloxycarbonylamino-2,4-dideoxy-α-D-ribopyranoside (**54**).* To a solution of **53** (250 mg, 0.58 mmol) in methanol was added sodium borohydride (40 mg, 1.06 mmol) with stirring at room temperature. After 30 min, the solution was neutralized with 1 M hydrochloric acid. After evaporation of the solution the resulting residue was dissolved in chloroform. The chloroform solution was washed with water, dried with anhydrous sodium sulfate and evaporated to give a syrup. The syrup was first crystallized by evaporation of ethanol solution after decolorization with activated charcoal. Yield, 94.4%: $[\alpha]_D$ +97.2° ($CHCl_3$); IR (KBr): 3450 and 3340 (OH and NH), 2075 (N_3), 1680 and 1495 (urethane), 740 and 695 (phenyl). Found: C, 60.25; H, 5.57; N, 13.93%. Calcd for $C_{20}H_{22}N_4O_5$: C, 60.29; H, 5.57; N, 14.16%. Its 3-acetate (**55**); Syrup, $[\alpha]_D$ +70.8° ($CHCl_3$); NMR: 4.78 (H_1: d, $J_{1,2}$=3.3), 4.14 (H_2: dt, $J_{2,3}$=3.0, $J_{NH,CH}$=9.6), 5.75 (H_3: t, $J_{3,4}$=3.0) 3.94 (H_{5a}: dd, $J_{4,5a}$=3.6, $J_{5a,5b}$=12.3), 3.64 (H_{5b}: dd, $J_{4,5b}$=6.8).

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