15. Total Synthesis of the Gastroprotective Substance AI-77-B and of Analogues[1])

by **Jean-Marc Durgnat**[2]) and **Pierre Vogel***

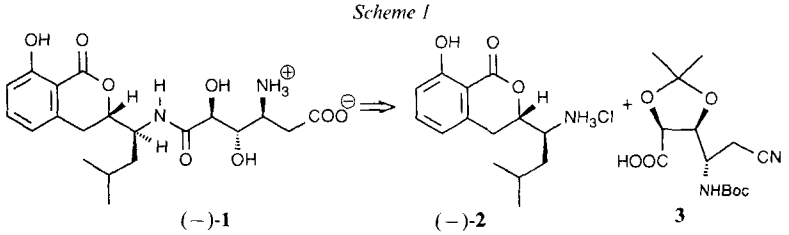
Section de Chimie de l'Université, rue de la Barre 2, CH–1005 Lausanne

(22.VIII.92)

The *Diels-Alder* adducts **8** of furan to 1-cyanovinyl acetate were converted into (methyl 3-chloro-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-α-DL-*arabino*-hexofuranosid)uronic acid ((±)-**18a**) and into (methyl 3-azido-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-α-DL-*ribo*-hexofuranosid)uronic acid ((±)-**41a**). These compounds were condensed to (3*S*)-3-[(1′*S*)-1′-amino-3′-methylbutyl]-3,4-dihydro-8-hydroxyisocoumarin hydrochloride ((−)-**2**); the resulting mixtures of diastereoisomeric amides were transformed and separated to give the gastroprotective substance AI-77-B ((−)-**1**) and analogues.

Introduction. – The AI-77's are a group of related 8-hydroxyisocoumarin derivatives isolated from the culture broth of *Bacillus pumilus* BN 103 [2]. One of the major component, AI-77-B ((−)-**1**), was shown to have a potent antiulcerogenic activity against stress ulcers without anticholinergic, antihistaminergic, or central suppressive effects [3]. The absolute configuration of **1** was determined from spectral data and by X-ray diffraction studies together with chemical studies [4]. This new class of antiulcer agents led *Shioiri* and coworkers [5] to complete the first total synthesis of AI-77-B ((−)-**1**) in 1989 by coupling the aminodihydroisocoumarin (−)-**2** to the partially protected (2*S*,3*S*,4*S*)-4-amino-5-cyano-2,3-dihydroxypentanoic-acid derivative **3** (see *Scheme 1*); the latter was

Scheme 1

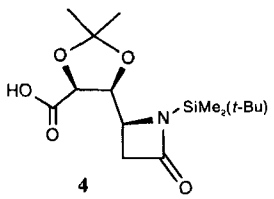


(−)-**1** (−)-**2** **3**

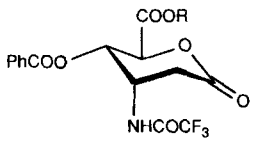
derived from D-glutamic acid. The second synthesis of (−)-**1** was reported in 1991 by *Thomas* and coworkers [6] who condensed (−)-**2** with the β-lactame derivative **4** derived from L-aspartic acid. *Gesson* and coworkers [7] obtained the protected forms **5** of the (2*S*,3*S*,4*S*)-3-amino-2,3-dihydroxyhexanedioic acid moiety of (−)-**1** from methyl 2,3-dideoxy-4,6-*O*-benzylidene-3-(trifluoroacetamido)-α-D-*ribo*-hexopyranoside. More recently, *Ward* and *Procter* [8] synthesized (−)-**1** from (*S*)-leucine and (*S*)-aspartic acid.

[1]) 'Naked Sugar' as Synthetic Intermediates, Part XXIII. Part XXII, see [1]. This work was presented at the autumn meeting of the Swiss Chemical Society, Bern, Oct. 18, 1991.

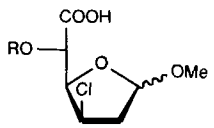
[2]) Present address: Department of Chemistry, University of California in Los Angeles.



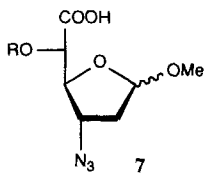
4



5



6

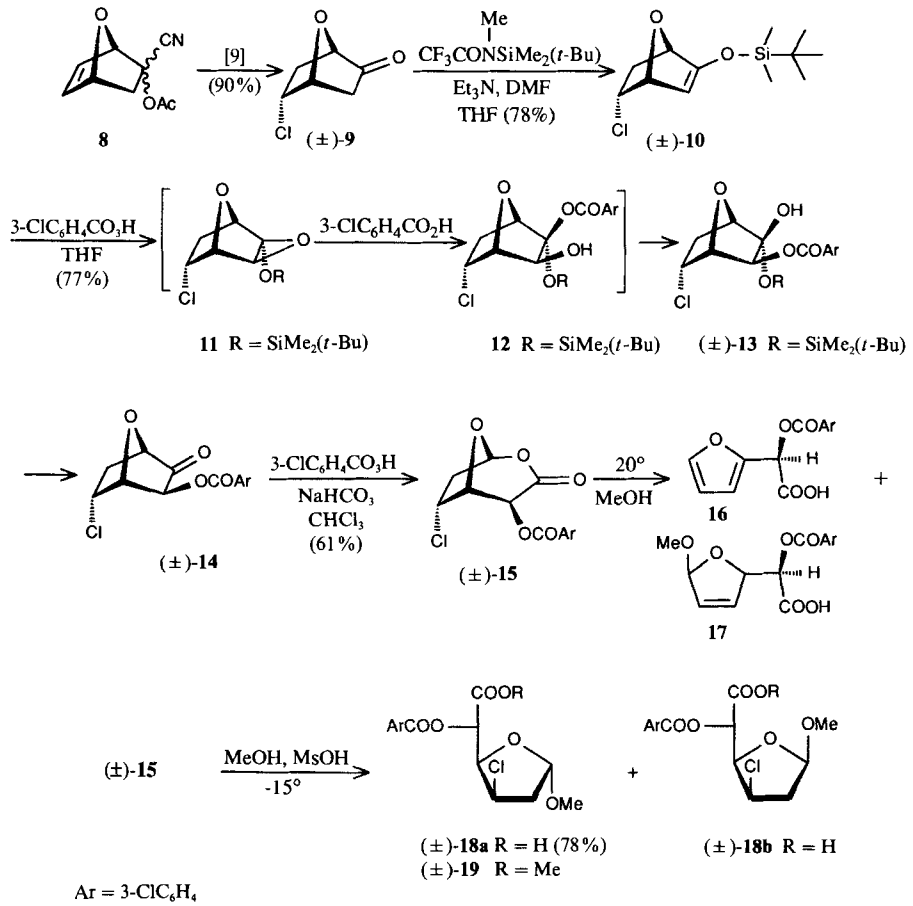


7

We report here a new approach to the total synthesis of (−)-**1** and analogues starting with 7-oxabicyclo[2.2.1]hept-5-en-2-yl derivatives ('naked sugars') for which we have developed methods that transform these readily available synthetic intermediates into all kinds of rare D- or L-hexose derivatives and analogues [9]. Our first strategy planned the condensation of (−)-**2** to the partially protected 3-chloro-2,3-dideoxy-*arabino*-hexofuranuronic acid derivatives **6** and the subsequent S_N2 displacement of the chloride by an azide moiety. A better alternative appeared to be that involving the condensation of (−)-**2** to (methyl 3-azido-2,3-dideoxy-*ribo*-α-D-hexofuranosid)uronic-acid derivative **7**, followed by the one-step oxidation of the furanoside moiety into the corresponding aldonolactone.

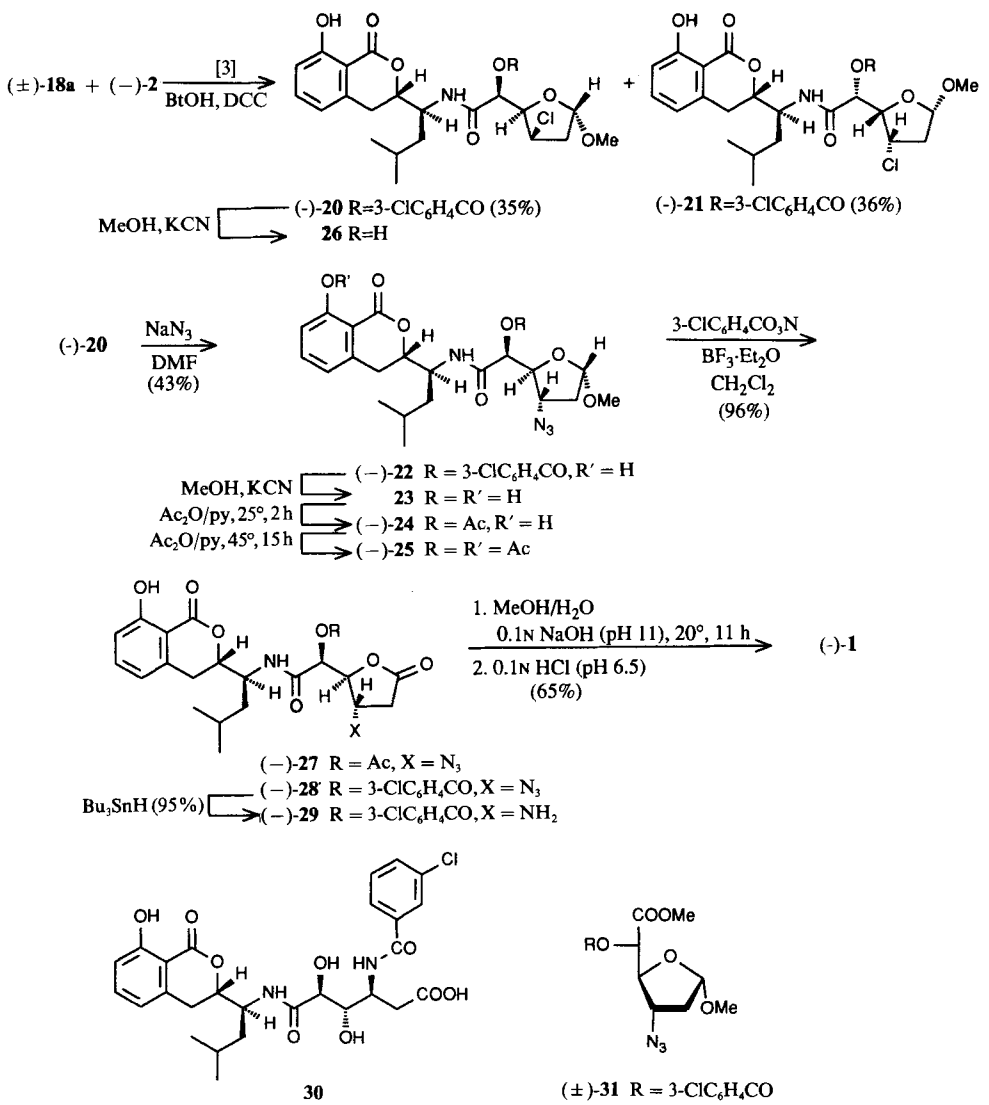
Results and Discussion. – The mixture of *Diels-Alder* adducts **8** of furan to 1-cyanovinyl acetate was converted into the chloroketone (±)-**9** (90%) following the procedure developed by *Warm* and *Vogel* [10] (*Scheme 2*). Treatment of (±)-**9** with 1.2 equiv. of *N*-[(*tert*-butyl)dimethylsilyl]-2,2,2-trifluoro-*N*-methylacetamide and 2 equiv. of Et_3N [11] led to the corresponding silyl enol ether (±)-**10** (78%). In CH_2Cl_2, (±)-**10** reacted with 55% 3-chloroperbenzoic acid (3-$ClC_6H_4CO_3H$) already at −78°. The reaction was retarded in the presence of tetrahydrofuran (THF). With 1.1 equiv. of 3-$ClC_6H_4CO_3H$ (THF, 25°, 2 h), compound (±)-**13** was isolated in 77% yield. It resulted probably from the acidolysis of the intermediate epoxide **11** by 3-$ClC_6H_4CO_2H$, leading to the hypothetical adduct **12** that underwent an acyl-group migration to give (±)-**13** [12] [13]. Heating (±)-**13** to 180° for 10 min provided the protected α-hydroxyketone (±)-**14** [14] which was reacted with 1.1 equiv. of 3-$ClC_6H_4CO_3H$ in the presence of $NaHCO_3$ to furnish the corresponding lactone (±)-**15** (61% based on (±)-**13**). This compound was unstable at room temperature, reacting with MeOH to give **16** and **17** together with HCl and polymeric material. Treatment of (±)-**15** with MeOH and 1.1 equiv. of methanesulfonic acid at −15° gave a 95:5 mixture of the methyl furanosides (±)-**18a** and (±)-**18b**. This product ratio decreased to 78:22 when the acidic methanolysis of (±)-**15** was carried out at 0°. Pure (±)-**18a** (78%) was obtained by crystallization from $CHCl_3$/hexane. Treatment of (±)-**18a** with CH_2N_2 in MeOH afforded the corresponding methyl uronate (±)-**19** (80%).

Scheme 2



The reaction of (±)-**18a** with benzotriazol-1-ol (BtOH) and dicyclohexylcarbodiimide (DCC) in CH_2Cl_2/DMF 3:1 (0°, 20 min) followed by the addition of 1 equiv. of (−)-**2** (prepared according to [5]) and of Et_3N in CH_2Cl_2/DMF 3:1 led to a 1:1 mixture of the corresponding amides (−)-**20** and (−)-**21** which were readily separated and purified by flash column chromatography (FC) on silica gel (35 and 36% yield, resp.; *Scheme 3*). Heating (−)-**20** in DMF to 110° in the presence of NaN_3 led to only 43% of the expected azido derivative (−)-**22**, together with products of decomposition. The use of azide-anion sources such as CsN_3 or $(Bu_4N)N_3$ were less successful than NaN_3. The selective saponification of the 3-chlorobenzoate moiety of (−)-**22** was carried out with anhydrous MeOH containing a catalytic amount of KCN and gave the corresponding alcohol **23** that was characterized as the monoacetate (−)-**24** obtained by treatment (25°, 2 h) with Ac_2O pyridine. On prolonged heating with Ac_2O/pyridine (45°, 15 h), the diacetate (−)-**25** was obtained in 96% yield. Saponification of (−)-**20** (MeOH, KCN, 20°) afforded **26**, the treatment of which with NaN_3 or CsN_3 in DMF failed to give **23**.

Scheme 3



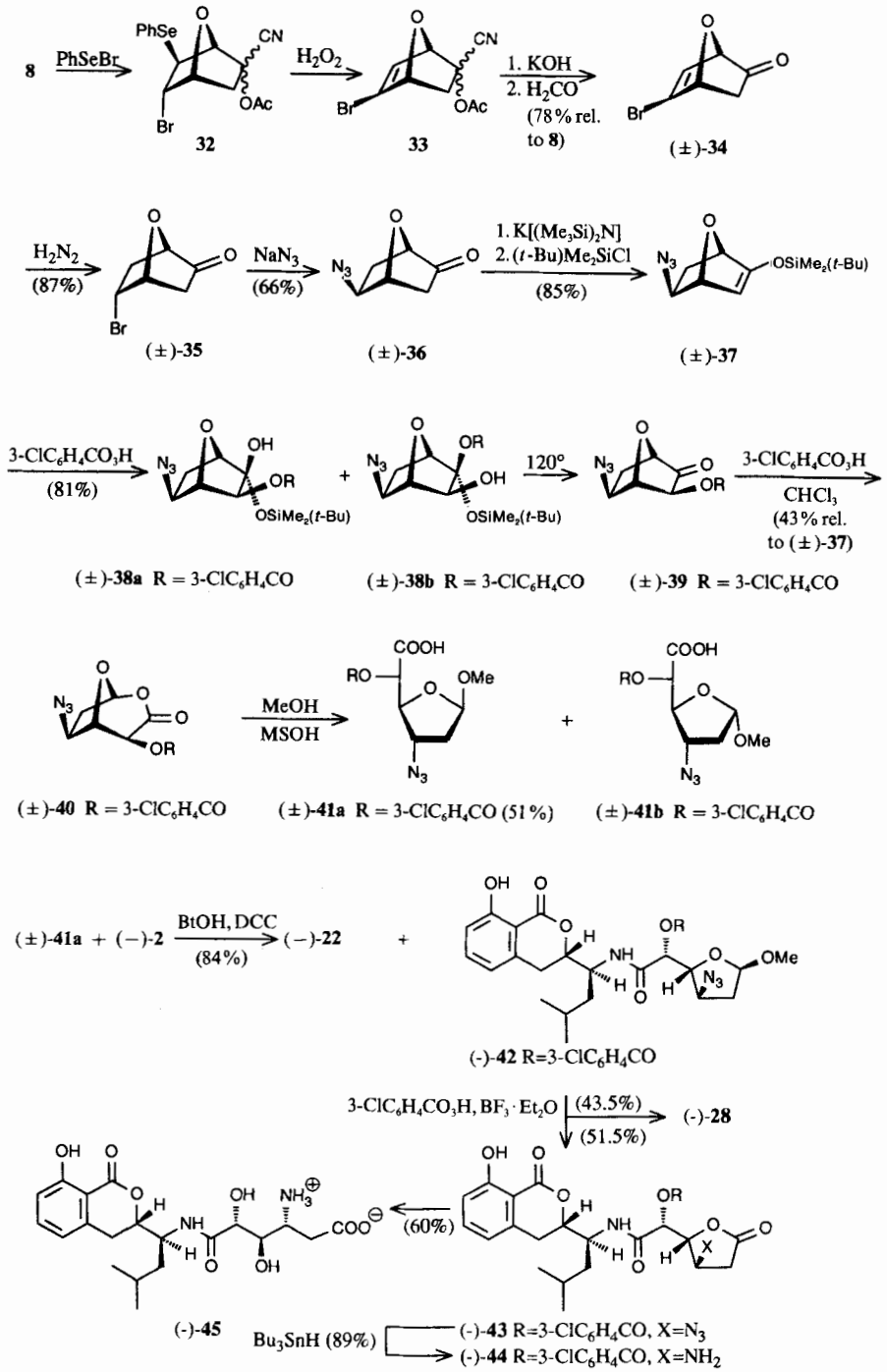
Among the different methods existing for the conversion of a methyl furanoside into the corresponding aldonolactone [15], we chose that proposed by *Grieco* and coworkers [16] which transformed (−)-**25** into (−)-**27** (66%) by treatment with 3 equiv. of 3-$ClC_6H_4CO_3H$ and 0.1 equiv. of $BF_3 \cdot Et_2O$ (25°, CH_2Cl_2). Under these acidic conditions, the phenolic acetate moiety was cleaved. The same procedure applied to the chlorobenzoate (−)-**22** afforded (−)-**28** in 96% yield. Reduction of the azide moiety in (−)-**28** with H_2 in the presence of a catalytic amount of 5% Pd/C in 50% aqueous THF (25°) gave a 1:1 mixture of (−)-**29** and of an unknown compound. In AcOEt/AcOH 95:5, the same

hydrogenation led to a 7:1 mixture of (−)-**29** and the same unknown compound. Reduction of (−)-**27** with Ph_3P [17] afforded the desired amine (−)-**29** in a mediocre yield (15–25%). Finally, under the conditions described by *Camano* and *Robbins* [18] using tributylstannane (benzene, 80°, 30 min), (−)-**29** was obtained pure in 95% yield. Under the conditions used by *Thomas* and coworkers [6] for the saponification of the aldonolactone moiety (50% aqueous EtOH, pH 9), (−)-**29** was converted into a 1:1 mixture of AI-77-B ((−)-**1**) and **30**. When employing MeOH/H_2O 1:1 instead of EtOH/H_2O 1:1 as solvent (0.1N NaOH, pH 11), the acyl migration leading to **30** was significantly retarded (probably because of the higher reactivity of MeOH compared with that of EtOH toward the lactone), and (−)-**1** was obtained as unique product of the aldonolactone hydrolysis. After neutralization with 0.1N HCl (pH 6.5) and purification by filtration on *Amberlite XAD-2* and column chromatography, (−)-**1** was obtained in 65% yield. Its physical and spectral data were identical to those reported for this compound in the literature.

Because of the relatively low yield (43%) obtained in the chloride displacement reaction (−)-**20**→(−)-**22**, we examined the possibility to introduce the azido group earlier in our synthesis. We first found that (±)-**19** could be converted into (±)-**31** (69%) on heating (120°) in anhydrous DMF with 3 equiv. of CsN_3. Attempts employing LiN_3, NaN_3, and $(Bu_4N)N_3$ all failed to give (±)-**31**. Attempts to substitute the *endo*-Cl-atom in the bicyclic ketone (±)-**9** (*Scheme 2*) *via* S_N2 displacement with azide anion failed also, probably because of the too low nucleofugacity of the Cl-atom. To circumvent this difficulty, we prepared the bromoketone (±)-**34** from **8** as shown in *Scheme 4*. Addition of benzeneselenenyl bromide to **8** [19] gave adduct **32**, the oxidation of which with 30% H_2O_2 in THF afforded the bromoalkene **33**. The latter was saponified with 4N KOH into the corresponding cyanohydrine that afforded the bromoenone (±)-**34** in 78% yield (based on **8**). Reduction of the alkene moiety in (±)-**34** with diimide [20] led to (±)-**35** (87%). The treatment of (±)-**35** with an excess of NaN_3 (5 equiv.) in DMF (110°, 12 h) afforded the azido-ketone (±)-**36** in 66% yield. Better yields could not be obtained with CsN_3, LiN_3 or $(Bu_4N)N_3$. Deprotonation of (±)-**36** with potassium bis[trimethylsilyl]-amide ($K[(Me_3Si)_2N]$) in THF (−78°) followed by reaction with (*t*-Bu)Me_2SiCl provided the silyl enol ether (±)-**37** (85%). Lithium diisopropylamide was not sufficient to carry out this transformation. Treatment of (±)-**37** with 3-$ClC_6H_4CO_3H$ in THF (25°) gave a mixture of (±)-**38a** and (±)-**38b** (structure established, as for (±)-**13**, by NOE measurements in the 360-MHz in ^{1}H-NMR spectrum) which was converted into the protected α-hydroxyketone (±)-**39** on heating to 120° for 10 min. *Baeyer-Villiger* oxidation of (±)-**39** with 3-$ClC_6H_4CO_3H$ in $CHCl_3$ (0°) afforded the uronolactone (±)-**40** (43% based on (±)-**37**). The high regioselectivity of this oxidation paralleled that transforming (±)-**14** into (±)-**15** and that of other 7-oxabicyclo[2.2.1]heptan-2-one derivatives [9] [21]. Acidic methanolysis (MeOH, $MeSO_3H$, −15°) of (±)-**40** gave a 9:1 mixture of the methyl furanosides (±)-**41a** and (±)-**41b** (63%) from which pure (±)-**41a** could be isolated by crystallization from $CHCl_3$/pentane (51%). Treatment of (±)-**41a** with BtOH/DDC and then with (−)-**2** gave a 1:1 mixture of amides (−)-**22** and (−)-**42** (84%) that could not be separated by usual chromatographic techniques.

Treatment of the mixture (−)-**22**/(−)-**42** with 1.1 equiv. of 3-$ClC_6H_4CO_3H$ and 0.1 equiv. of $BF_3 \cdot Et_2O$ in CH_2Cl_2 at 25° gave a 1:1 mixture of aldonolactones (−)-**28** and (−)-**43** that were readily separated by flash chromatography on silica gel. The diastereoisomer (−)-**28** was transformed (*Scheme 3*) into (−)-**1**, whereas (−)-**43** was reduced

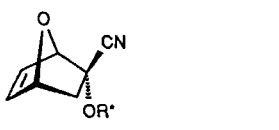
Scheme 4


8
PhSeBr
32
H_2O_2
33
1. KOH
2. H_2CO
(78% rel. to 8)
(±)-34
H_2N_2
(87%)
(±)-35
NaN_3
(66%)
(±)-36
1. $K[(Me_3Si)_2N]$
2. (t-Bu)Me_2SiCl
(85%)
(±)-37
3-$ClC_6H_4CO_3H$
(81%)
120°
3-$ClC_6H_4CO_3H$
$CHCl_3$
(43% rel. to (±)-37)
(±)-38a R = 3-ClC_6H_4CO
(±)-38b R = 3-ClC_6H_4CO
(±)-39 R = 3-ClC_6H_4CO
MeOH
MSOH
(±)-40 R = 3-ClC_6H_4CO
(±)-41a R = 3-ClC_6H_4CO (51%)
(±)-41b R = 3-ClC_6H_4CO
(±)-41a + (−)-2
BtOH, DCC
(84%)
(−)-22
(-)-42 R=3-ClC_6H_4CO
3-$ClC_6H_4CO_3H$, $BF_3 \cdot Et_2O$
(43.5%)
(51.5%)
(-)-28
(60%)
(-)-45
Bu_3SnH (89%)
(-)-43 R=3-ClC_6H_4CO, X=N_3
(-)-44 R=3-ClC_6H_4CO, X=NH_2

with Bu_3SnH giving (−)-**44** and then saponified ($MeOH/H_2O$ 1:1, 0.1N NaOH) to yield the stereoisomer (−)-**45**, the physical and spectral data of which were quite different from those reported for (−)-**1** (see *Exper. Part*).

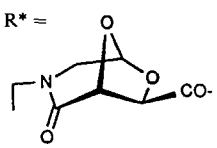
The structures of the new compounds described in this work were established unambiguously by their mode of formation, their reactivity, and by their spectral data. The ^{1}H-NMR signal attributions were confirmed by double-irradiation experiments, including nuclear *Overhauser* effect (NOE) measurements.

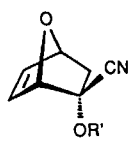
Conclusion. – The racemic *Diels-Alder* adduct mixture **8** of furan to 1-cyanovinyl acetate was converted into AI-77-B ((−)-**1**) following two procedures that condense the (*S*)-leucine-derived (3*S*)-3-[(1′*S*)-1′-amino-3′-methylbutyl]-3,4-dihydro-8-hydroxyisocoumarin hydrochloride ((−)-**2**) to either (methyl 3-chloro-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-α-DL-*arabino*-hexofuranosid)uronic acid ((±)-**18a**) or (methyl 3-azido-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-α-DL-*ribo*-hexofuranosid)uronic acid ((±)-**41a**). The first approach led to an overall yield of 1.5% (based on **8**) and implied the isolation of 12 intermediates, whereas the second method gave an overall yield for (−)-**1** of 1.8% (based on **8**) and required the isolation of 10 intermediates. The uronic-acid derivatives (±)-**18a** (6 steps from **8**, 26% overall yield) and (±)-**41a** (6 steps form **8**, 8.3% overall yield) can be prepared optically pure in both enantiomeric forms starting from the readily prepared optically pure 'naked sugars' (+)-**46** (or (+)-**47**) and (−)-**48** (or (−)-**49**) [8] [22]. Our



(+)-**46** R* = (1*S*)-camphanoyl

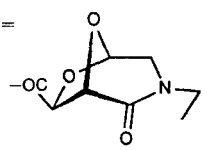
(+)-**47** R* =





(−)-**48** R′ = (1*R*)-camphanoyl

(−)-**49** R′ =



methodology is thus applicable, in principle, to the total synthesis of AI-77-B and its analogues without the necessity of a chromatographic separation of diastereoisomeric intermediates and thus, our overall yields for (−)-**1** should be at least the double of those given here.

We thank the *Swiss National Science Foundation*, *F. Hoffmann-La Roche AG*, Basel, and the *Fonds Herbette*, Lausanne, for generous financial support.

Experimental Part

General. See [23]. None of the procedures was optimized.

*(±)-2-{[(*tert*-Butyl)dimethylsilyl]oxy}-5-*endo*-chloro-7-oxabicyclo[2.2.1]hept-2-ene* ((±)-**10**). A mixture of (±)-**9** [9] (1 g, 6.82 mmol), Et_3N (2 ml), anh. DMF, and *N*-[(*tert*-butyl)dimethylsilyl]-2,2,2-trifluoro-*N*-methylacetamide (1.3 ml, 7.5 mmol) was stirred at 75° for 20 h. The solvent was distilled off (50°/0.05 Torr) and the residue purified by filtration on silical gel (*Merck 9385*, 60 g, AcOEt/light petroleum 1:12): 1.38 g (78%). Colourless crystals. M.p. 41–42°. IR (KBr): 2950, 1625, 1470, 1340, 1310, 1260, 1220, 1210, 1155, 1120, 1025. ^{1}H-NMR (250 MHz, $CDCl_3$): 5.03 (*d*, ^3J = 2.0, H–C(3)); 4.9 (*ddd*, ^3J = 4.2, 2.0, ^4J = 1.0, H–C(4)); 4.54 (*dd*, ^3J = 4.5, ^4J = 1.0, H–C(1)); 4.32 (*ddd*, ^3J = 9.0, 4.2, 3.0, H–C(5)); 2.46 (*ddd*, ^2J = 12.2, ^3J = 9.0, 4.5, H_{exo}–C(6)); 1.45 (*dd*, ^2J = 12.2, ^3J = 3.0, H_{endo}–C(6)); 0.95 (*s*, *t*-Bu); 0.22, 0.18 (2*s* Me_2Si). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 162.6 (*s*, C(2)); 100.5 (*d*, ^1J(C,H) = 173, C(3)); 81.6 (*d*, ^1J(C,H) = 160, C(1)); 80.2 (*d*, ^1J(C,H) = 163, C(4)); 54.9 (*d*, ^1J(C,H) = 160, C(5)); 36.0 (*t*, ^1J(C,H) = 141, C(6)); 29.7 (*s*, Me_3C); 25.5 (*q*, ^1J(C,H) = 125, Me_3C). CI-MS (NH_3): 279 (100 [M + 19]$^+$), 260 (1, $M^{+\cdot}$), 223 (5), 168 (7), 167 (52), 150 (12), 149 (90), 132 (6), 121 (5), 113 (16), 112 (19), 105 (13), 104 (26), 97 (10), 95 (9), 91 (7), 84 (8), 83 (31), 81 (13), 77 (11), 76 (19), 71 (58), 70 (50). Anal. calc. for $C_{12}H_{21}ClO_2Si$ (260.85): C 55.25, H 8.11; found: C 55.19, H 8.04.

*(1RS,2SR,3RS,4RS,6RS)-3-*endo-*{[(*tert*-Butyl)dimethylsilyl]oxy}-6-*endo-*chloro-3-*exo-*hydroxy-7-oxabicyclo[2.2.1]hept-2-*exo-*yl 3-Chlorobenzoate* ((±)-**13**). A mixture of (±)-**10** (550 mg, 2.07 mmol), THF (10 ml), 3-$ClC_6H_4CO_3H$ (85%, *Fluka*; 462 mg, 2.28 mmol) was stirred at 25° for 1 h (TLC control, AcOEt/light petroleum 1:3): R_f 0.7, ((±)-**10**), 0.4 ((±)-**13**)). After evaporation the residue was purified by column chromatography (CC; silica gel *Merck 9385* (25 g), 0°, AcOEt/light petroleum ether 1:11): 688 mg (77%). White powder. M.p. 100–102° (dec.). IR (KBr): 3400, 2950, 2800, 1790, 1700, 1430, 1285, 1160, 1120, 1000, 870, 840, 775. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.05, 7.95, 7.60, 7.43 (4 H, arom. CH); 5.52 (*s*, H–C(2)); 4.50 (*dd*, ^3J = 5.2, ^4J = 1.3, H–C(4)); 4.24 (*ddd*, ^3J = 10.1, 5.1, 4.8, H–C(6)); 4.20 (*dd*, ^3J = 5.1, ^4J = 1.3, H–C(1)); 2.4 (*ddd*, ^2J = 13.2, ^3J = 10.1, 5.2, H_{exo}–C(5)); 2.23 (*dd*, ^2J = 13.2, ^3J = 4.8, H_{endo}–C(5)); 0.9 (*s*, *t*-Bu); 0.13 (2*s*, Me_2). CI-MS (NH_3): 451 (2, [M + 18]$^+$), 246 (6), 232 (5), 147 (5), 144 (4), 131 (4), 122 (8), 117 (12), 110 (6), 109 (7), 107 (12), 106 (19), 105 (34), 104 (15), 98 (26), 91 (100), 81 (25), 78 (40), 70 (22). Anal. calc. for $C_{19}H_{25}Cl_2O_5Si$ (432.38): C 52.77, H 5.82; found: C 52.83, H 5.89.

*(1RS,2SR,4RS,6RS)-6-*endo-*Chloro-3-oxo-7-oxabicyclo[2.2.1]hept-2-*exo-*yl 3-Chlorobenzoate* ((±)-**14**). Under stirring, (±)-**13** (0.5 g, 1.15 mol) was heated to 180° for 10 min. After cooling to 0°, the solid residue was washed with hexane (5 ml) and then dissolved in a small amount of CH_2Cl_2. After addition of hexane (diffusion CH_2Cl_2/hexane), 1.84 mg (53%) of white crystals were collected. M.p. 161–162°. UV (95% EtOH): 270 (200), 230 (2260); final absorption: ε_{210} = 11800. IR (KBr): 3300, 1785, 1725, 1570, 1430, 1255, 1120, 995, 940, 775, 745. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.05, 7.95, 7.60, 7.41 (4 H, arom. CH); 5.87 (*s*, H–C(2)); 4.88 (*d*, ^3J = 5.2, H–C(1)); 4.52 (*d*, ^3J = 6.7, H–C(4)); 4.33 (*ddd*, ^3J = 10.2, 5.2, 4.8, H–C(6)); 2.82 (*ddd*, ^2J = 13.9, ^3J = 10.2, 6.7, H_{exo}–C(5)); 1.90 (*dd*, ^2J = 13.9, ^3J = 4.8, H_{endo}–C(5)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 203.0 (*s*, C(3)); 164.0 (*s*, Ph*C*O); 136.5, 134, 130.6, 130.1, 130.0, 128.2 (6 arom. C); 82.8 (*d*, ^1J(C,H) = 165, C(2)); 79.3 (*d*, ^1J(C,H) = 168, C(4)); 71.2 (*d*, ^1J(C,H) = 156, C(1)); 51.3 (*d*, ^1J(C,H) = 164, C(6)); 35.9 (*t*, ^1J(C,H) = 137, C(5)). EI-MS (70 eV): 302 (1, [M + 1]$^+$), 301 (1), 300 (1), 141 (30), 139 (100), 113 (10), 111 (3), 76 (9), 75 (27), 74 (27), 69 (6), 53 (7), 51 (6), 50 (9). Anal. calc. for $C_{13}H_{10}Cl_2O_4$ (301.13): C 51.85, H 3.34; found: C 51.90, H 3.37.

*3-Chloro-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-β-*DL*-*arabino*-hexofuranurono-6,1-lactone* ((±)-**15**). Under N_2, (±)-**13** (1 g, 2.3 mmol) was heated to 180° for 10 min. The brownish liquid solidified on cooling to 0°. It was dissolved in $CHCl_3$ (8 ml), and $NaHCO_3$ (200 mg, 2.4 mmol) was added. A soln. of 3-$ClC_6H_4CO_3H$ (85%; 515 mg, 2.53 mmol) in $CHCl_3$ (5 ml) was then added dropwise under stirring. The reaction was instantaneous (TLC control (CH_2Cl_2/AcOEt 30:1): same R_f for (±)-**15** and (±)-**14**, but only (±)-**15** gave a black spot with vanilin). Evaporation and CC (*Florisil*, CH_2Cl_2/light petroleum ether 3:1, R_f ((±)-**15**) 0.33) yielded 446 mg (61%). Unstable, colourless oil, can be stored in $CHCl_3$ soln. at −20°. UV (95% EtOH): ε_{230} = 1430, ε_{220} = 10950. UV (Et_2O): ε_{231} = 3675, ε_{210} = 11250. IR (CH_2Cl_2): 3060, 1770, 1735, 1475, 1425, 1380, 1295, 1240, 1200, 1165, 1120, 1070, 1000. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.08, 8.00, 7.61, 7.45 (4 H, arom. CH); 6.20 (*d*, ^3J = 0.7, H–C(5)); 6.02 (*d*, ^3J = 4.5, H–C(1)); 4.91 (*dd*, ^3J = 6.7, 0.7, H–C(4)); 4.61 (*ddd*, ^3J = 10.5, 6.7, 4.8, H–C(3)); 3.00 (*ddd*, ^2J = 14.5, ^3J = 10.5, 4.5, H_{exo}–C(2)); 2.40 (*dd*, ^2J = 14.5, ^3J = 4.8, H_{endo}–C(2)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 163.0, 162.0, (2*s*, 2 CO); 134.7, 133.8, 130.3, 130.0, 129.9, 128.2 (6 arom. C); 102.2 (*d*, ^1J(C,H) = 186, C(1)); 80.6 (*d*, ^1J(C,H) = 164, C(5)); 68.8 (*d*, ^1J(C,H) = 151, C(4)); 50.3 (*d*, ^1J(C,H) = 160, C(3)); 42.8 (*t*, ^1J(C,H) = 138, C(2)). EI-MS (70 eV): 316 (27, $M^{+\cdot}$), 206 (21), 168 (30), 164 (25), 126 (46), 125 (32), 124 (24), 120 (33), 117 (29), 115 (26), 111 (34), 97 (30), 96 (62), 91 (59), 86 (29), 83 (55), 82 (81), 78 (100), 73 (31).

*(Methyl 3-Chloro-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-α-*DL*-*arabino*-hexofuranosid)uronic Acid* ((±)-**18a**). MsOH (226 µl, 3.5 mmol) was added dropwise under stirring to a soln. of (±)-**15** (1 g, 3.15 mmol) in anh. MeOH (20

ml) cooled to −15°. After stirring at −15° for 30 min (TLC control, AcOEt/light petroleum ether 1:3), AcONa (517 mg, 6.3 mmol) was added to precipitate MsONa. Evaporation CC (silica gel (60 g), CH_2Cl_2/MeOH 9:1, R_f 0.1 ((±)-**18a**) and 0.2 ((±)-**18b**)), and recystallization from $CHCl_3$/pentane of the 2nd fraction yielded 859 mg (78%) of (±)-**18a**. White crystals. M.p. 138°. UV (95% EtOH): 283 (150), 231 (350), ε_{210} = 12500. IR (CH_2Cl_2): 3090, 2900, 2890, 2380, 1760, 1730, 1575, 1470, 1425, 1380, 1355, 1295, 1245, 1190, 1120, 1100, 1065, 1025, 1000, 950. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.01, 7.94, 7.59, 7.42 (4 H, arom. CH); 5.50 (*d*, ^3J = 8.5, H–C(5)); 5.34 (*dd*, ^3J = 5.3, 3.5, H–C(1)); 4.70 (*ddd*, ^3J = 6.0, 4.1, 3.0, H–C(3)); 4.65 (*dd*, ^3J = 8.5, 4.1, H–C(4)); 3.40 (*s*, MeO); 2.61 (*ddd*, ^2J = 15.0, ^3J = 5.3, 3.0, H–C(2) *trans* to Cl); 2.48 (*ddd*, ^2J = 15.0, ^3J = 6.0, 3.5, H–C(2) *cis* to Cl). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 171.5, 163.9, (2*s*, 2 CO); 134.7, 133.6, 130.4, 130.0, 129.9, 128.1 (6 arom. C); 104.8 (*d*, ^1J(C,H) = 169, C(1)); 77.9 (*d*, ^1J(C,H) = 153, C(5)); 71.6 (*d*, ^1J(C,H) = 153, C(4)); 58.4 (*d*, ^1J(C,H) = 163, C(3)); 56.0 (*q*, MeO); 43.5 (*t*, ^1J(C,H) = 133, C(2)). EI-MS (70 eV): 368 (3, $[M + 19]^+$), 366 (4, $[M + 17]^+$), 317 (12), 275 (4), 253 (10), 227 (3), 141 (7), 139 (13), 113 (11), 111 (14), 99 (35), 93 (12), 91 (11), 77 (14), 76 (15), 74 (22), 72 (8), 75 (32), 71 (100), 69 (14), 51 (9). Anal. calc. for $C_{14}H_{14}Cl_2O_6$ (349.17): C 48.16, H 4.04; found: C 48.21, H 4.05.

*Methyl (Methyl 3-Chloro-5-*O*-(3-chlorobenzoyl)-2,5-dideoxy-α-*DL-arabino-*hexofuranosid)uronate* ((±)-**19**). A soln. of CH_2N_2 in Et_2O was added (until persistence of the yellow colour) to a stirred soln. of (±)-**18a** (1 g, 2.86 mmol) in MeOH (20 ml) acidified to pH 2 with 2N HCl and cooled to 0°. The temp. was allowed to reach 20°, the solvent evaporated, and the residue purified by CC (silica gel (70 g), AcOEt/light petroleum ether 1:4, R_f 0.33 ((±)-**19**)). 916 mg (80%). Colourless oil. IR ($CHCl_3$): 3670, 3250, 2950, 2450, 2105, 1730, 1670, 1670, 1575, 1385, 1360, 1295, 1200, 1110, 1030, 955, 646. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.15, 7.95, 7.59, 7.43 (4 H, arom. C); 5.41 (*d*, ^3J = 8.5, H–C(5)); 5.43 (*dd*, ^3J = 5.3, 3.6, H–C(1)); 4.71 (*ddd*, ^3J = 6.3, 3.9, 3.0, H–C(3)); 4.61 (*dd*, ^3J = 8.5, 3.9, H–C(4)); 3.86 (*s*, MeO); 3.38 (*s*, MeO); 2.61 (*ddd*, ^2J = 14.8, ^3J = 5.3, 3.0, H–C(2) *cis* to Cl); 2.45 (*ddd*, ^2J = 14.8, ^3J = 6.3, 3.6, H–C(2) *trans* to Cl). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 168.9, 164.0, (2*s*, 2 CO); 134.0, 133.6, 130.7, 130.0, 129.9, 128.1 (6 arom. C); 104.5 (*d*, ^1J(C,H) = 170, C(1)); 78.3 (*d*, ^1J(C,H) = 154, C(5)); 72.3 (*d*, ^1J(C,H) = 154, C(4)); 58.4 (*d*, ^1J(C,H) = 164, C(3)); 55.6 (*q*, MeO); 52.7 (*q*, CO_2Me); 43.6 (*t*, ^1J(C,H) = 132, C(2)). EI-MS (70 eV): 141 (24), 139 (100), 137 (13), 135 (45), 111 (41), 99 (70), 75 (20), 71 (71), 69 (12), 59 (10). Anal. calc. for $C_{15}H_{16}Cl_2O_6$ (363.18): C 49.60, H 4.44; found: C 49.51, H 4.44.

*(3S)-3,4-Dihydro-8-hydroxy-3-{(1′S)-3′-methyl-1′-{[(methyl 3″-chloro-5″-*O*-(3-chlorobenzoyl)-2″,3″-dideoxy-α-*D*-arabino-hexofuranosid)uronyl]amino}butyl}-1*H*-2-benzopyran-1-one* (= *{Methyl 3-Chloro-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-*N*-{(1′S)-1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl}-α-*D*-arabino-hexofuranosid}uronamide*; (−)-**20**) *and (3S)-3,4-Dihydro-8-hydroxy-3-{(1′S)-3′-methyl-1′-{[(methyl 3″-chloro-5″-*O*-(3-chlorobenzoyl)-2″,3″-dideoxy-α-*L*-arabino-hexofuranosid)uronyl]amino}butyl}-1*H*-2-benzopyran-1-one* (= *{Methyl 3-Chloro-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-*N*-{(1′S)-1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl}-α-*L*-arabino-hexofuranosid}uronamide*; (−)-**21**). BtOH (66 mg) and DCC (88 mg) were added to a stirred soln. of (±)-**18a** (170 mg, 0.5 mmol) in anh. CH_2Cl_2 (4 ml) and anh. DMF (1.4 ml) cooled to 0°. The soln. was stirred at 0° for 20 min. The precipitate was filtered off and the soln. was added to a soln. of (3*S*)-3-[(1′*S*)-1′-amino-3′-methylbutyl]-3,4-dihydro-8-hydroxy-1*H*-2-benzopyran-1-one [5] ((−)-**2**; 140 mg, 0.5 mmol) in anh. CH_2Cl_2 (1.8 ml) and DMF (0.6 ml) containing anh. Et_3N (68 µl) within 15 min under Ar. The mixture was stirred at 25° for 30 min. (TLC control, AcOEt/light petroleum ether 1:2) and evaporated and the residue purified by CC (silica gel (10 g), AcOEt/light petroleum ether 1:12). A 1st fraction yielded 101 mg (35%) of (−)-**20**, and a 2nd fraction afforded 102.2 mg (36%) of (−)-**21**.

Characteristics of (−)-**20**. M.p. 98–99°. $[\alpha]_{589}^{25} = -113$, $[\alpha]_{578}^{25} = -132$, $[\alpha]_{546}^{25} = -120$, $[\alpha]_{436}^{25} = -142$, $[\alpha]_{365}^{25} = -208$ (*c* = 0.13, CH_2Cl_2). IR (KBr): 3320, 2940, 1760, 1680, 1620, 1540, 1460, 1300, 1280, 1120, 1030, 1010, 950, 910, 875, 810, 745. ^{1}H-NMR (250 MHz, $CDCl_3$): 10.85 (*s*, OH); 8.00, 7.92, 7.58, 7.43 (4 H, arom. CH); 7.43 (*dd*, ^3J = 8.5, 7.5, H–C(6)); 6.91, 6.74 (2*d*, ^3J = 8.5, 7.5, H–C(5), H–C(7)); 6.36 (*d*, ^3J = 10.0, NH); 5.39 (*dd*, ^3J = 5.8, 4.6, H–C(1″)); 5.26 (*d*, ^3J = 9.5, H–C(5″)); 4.63 (*m*, H–C(3), H–C(3″)); 4.58 (*dd*, ^3J = 9.5, 3.0, H–C(4″)); 4.45 (*ddd*, ^3J = 9.3, 4.7, 1.1, H–C(1′)); 3.43 (*s*, MeO); 3.29 (*dd*, ^2J = 15.5, ^3J = 13.0, H_{trans}–C(4)[3])); 2.82 (*dd*, ^2J = 15.5, ^3J = 2.5, H_{cis}–C(4)[3]); 2.68 (*ddd*, ^2J = 15.0, ^3J = 5.8, 1.0, H_{cis}–C(2″)[4]); 2.48 (*ddd*, ^2J = 15.0, ^3J = 6.0, 4.6, H_{trans}–C(2″))[4]; 1.92 (*ddd*, ^2J = 13.8, ^3J = 10.3, 4.7, H–C(2′)); 1.74 (*ddq*, ^3J = 10.3, 6.4, 5.0, H–C(3′)); 1.47 (*ddd*, ^2J = 13.8, ^3J = 9.3, 5.0, H–C(2′)); 0.98 (2*d*, ^3J = 6.4, 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 169.2 (*s*, COO); 167.5, 163.4 (2*s*, 2 CO); 162.1 (*s*, C(8)); 139.8 (*s*, C(4a)); 136.5 (*s*, ^1J(C,H) = 160, arom. CH); 134.5 (*s*, arom. C); 133.5 (*d*, ^1J(C,H) = 180, C(6)); 130.6 (*s*, arom. C); 129.9, 129.8, 127.9 (3*d*, arom. C); 118.3,

[3]) With respect to O(2).

[4]) With respect to Cl.

118.3 (2*d*, ^1J(C,H) = 165, 163, C(5), C(7)); 108.0 (*s*, C(8a)); 105.4 (*d*, ^1J(C,H) = 172, C(1″)); 81.5 (*d*, ^1J(C,H) = 155, C(3)); 78.0 (*d*, ^1J(C,H) = 160, C(5″)); 73.0 (*d*, ^1J(C,H) = 152, C(4″)); 59.9 (*d*, ^1J(C,H) = 165, C(3″)); 56.2 (*q*, ^1J(C,H) = 143, MeO); 49.1 (*d*, ^1J(C,H) = 137, C(1′)); 43.5 (*dd*, ^1J(C,H) = 140, C(4)); 40.9 (*t*, ^1J(C,H) = 128, C(2″)); 30.2 (*t*, ^1J(C,H) = 132, C(2′)); 24.4 (*d*, ^1J(C,H) = 125, (C(3′)); 23.1, 21.8 (2*q*, ^1J(C,H) = 123, 2 Me–C(3′)). CI-MS (NH_3): 582 (8, $[M + 2]^+$), 385 (9), 357 (11), 356 (12), 333 (17), 318 (5), 298 (9), 288 (9), 263 (15), 261 (30), 249 (10), 231 (15), 224 (12), 215 (18), 196 (23), 193 (21), 157 (17), 139 (93), 133 (18), 112 (21), 111 (27), 105 (19), 99 (15), 91 (38), 75 (100). Anal. calc. for $C_{28}H_{31}Cl_2NO_8$ (580.47): C 57.90, H 5.34; found: C 57.80, H 5.17.

Characteristics of (–)-**21**. M.p. 97–98°. $[\alpha]_{589}^{25} = -11$, $[\alpha]_{578}^{25} = -15$, $[\alpha]_{546}^{25} = +4.3$, $[\alpha]_{436}^{25} = +53$, $[\alpha]_{365}^{25} = +148$ (*c* = 0.19, CH_2Cl_2). IR (KBr): 3330, 2950, 1760, 1675, 1620, 1540, 1460, 1160, 1110, 1090, 1030, 1010, 950, 805, 750. ^{1}H-NMR (250 MHz, $CDCl_3$): 10.6 (*s*, OH); 8.03, 7.94, 7.58, 7.41 (4 H, arom. CH); 7.41 (*dd*, ^3J = 8.5, 7.5, H–C(6)); 6.89, 6.70 (2*d*, ^3J = 8.5, 7.5, H–C(5), H–C(7)); 6.38 (*d*, ^3J = 9.7, NH); 5.32 (*d*, ^3J = 9.1, H–C(5″)); 5.27 (*dd*, ^3J = 5.8, 4.8, H–C(1″)); 4.64 (*m*, H–C(3), H–C(3″)); 4.60 (*dd*, ^3J = 9.1, 4.5, H–C(4″)); 4.44 (*ddd*, ^3J = 8.8, 4.9, 0.8, H–C(1′)); 3.22 (*dd*, ^2J = 16.5, ^3J = 13.0, H_{trans}–C(4))[3]); 3.10 (*s*, MeO); 2.86 (*dd*, ^2J = 16.5, ^3J = 2.5, H_{cis}–C(4))[3]); 2.62 (*ddd*, ^2J = 15.0, ^3J = 5.8, 1.0, H_{cis}–C(2″))[4]); 2.4 (*ddd*, ^2J = 15.0, ^3J = 6.0, 4.8, H_{trans}–C(2″))[4]); 1.91 (*ddd*, ^2J = 13.8, ^3J = 9.8, 4.9, H–C(2′)); 1.66 (*ddq*, ^3J = 9.8, 6.6, 5.0, H–C(3′)); 1.50 (*ddd*, ^2J = 13.8, ^3J = 8.8, 5.0, H–C(2′)); 0.98 (2*d*, ^3J = 6.6, 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 169.5 (*s*, arom. C); 167.5, 163.8 (2*s*, 2 CO); 162.1 (*s*, C(8)); 139.7 (*s*, C(4a)); 136.5 (*d*, ^1J(C,H) = 160, arom. CH); 134.6 (*s*, arom. C); 133.5 (*d*, ^1J(C,H) = 180, C(6)); 130.6 (*s*, arom. C); 129.8, 129.7, 128.0 (3*d*, arom. C); 118.1, 118.1 (2*d*, ^1J(C,H) = 165, 163, C(5), C(7)); 107.9 (*s*, C(8a)); 105.3 (*d*, ^1J(C,H) = 172, C(1″)); 81.3 (*d*, ^1J(C,H) = 155, C(3)); 78.1 (*d*, ^1J(C,H) = 160, C(5″)); 73.0 (*d*, ^1J(C,H) = 152, C(4″)); 59.6 (*d*, ^1J(C,H) = 165, C(3″)); 55.8 (*q*, ^1J(C,H) = 143, MeO); 49.2 (*d*, ^1J(C,H) = 137, C(1′)); 43.5 (*dd*, ^1J(C,H) = 140, C(4)); 40.6 (*t*, ^1J(C,H) = 128, C(2″)); 30.1 (*t*, ^1J(C,H) = 132, C(2′)); 24.6 (*d*, ^1J(C,H) = 125, C(3′)); 23.6, 21.9 (2*q*, ^1J(C,H) = 123, 2 Me–C(3′)). CI-MS (NH_3): 582 (11, $[M + 2]^+$), 581 (5, $[M + 1]^+$), 580 (6, M^+), 341 (6), 331 (7), 278 (8), 263 (10), 261 (26), 234 (10), 229 (11), 226 (6), 225 (38), 224 (31), 220 (9), 219 (9), 175 (9), 141 (15), 139 (19), 127 (12), 128 (12), 114 (8), 110 (14), 99 (38), 98 (21), 96 (12), 85 (48), 83 (37), 71 (100).

*(3S)-3,4-Dihydro-8-hydroxy-3-{(1′S)-3′-methyl-1′-{[(methyl 3″-azido-5″-O-(3-chlorobenzoyl)-2″,3″-dideoxy-α-*D*-ribo-hexofuranosid)uronyl]amino}butyl}-1*H*-2-benzopyran-1-one* (= {*Methyl 3-Azido-5-O-(3-chlorobenzoyl)-2,3-dideoxy*-N-{(1′S)-1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″H-2″-benzopyran-3″-yl]-3′-methylbutyl}-α-*D*-ribo-*hexofuranosid*}*uronamide*; (–)-**22**). A mixture of (–)-**20** (50 mg, 0.09 mmol), NaN_3 (78 mg, 0.45 mmol), and anh. DMF (1 ml) was heated to 110° for 12 h (TLC, AcOEt/light petroleum ether 1:3, R_f (0.3 (–)-**20**) and 0.4 ((–)-**22**)). Evaporation (0.1 Torr) and CC (silica gel, AcOEt/light petroleum ether 1:6) yielded 41 mg (43%). Colourless oil. $[\alpha]_{589}^{25} = -80$, $[\alpha]_{578}^{25} = -87$, $[\alpha]_{436}^{25} = -131$, $[\alpha]_{365}^{25} = -209$ (*c* = 0.74, CH_2Cl_2). IR ($CHCl_3$): 3420, 2950, 2100, 1760, 1680, 1580, 1460, 1230, 1110, 1045, 800. ^{1}H-NMR (250 MHz, $CDCl_3$): 10.79 (*s*, OH); 8.00, 7.91, 7.58, 7.43 (4 H, arom. CH); 7.43 (*dd*, ^3J = 8.5, 7.5, H–C(6)); 6.90, 6.71 (2*d*, ^3J = 8.5, 7.5, H–C(5), H–C(7)); 6.2 (*d*, ^3J = 10.0, NH); 5.32 (*d*, ^3J = 5.0, H–C(5″)); 5.03 (*dd*, ^3J = 5.2, 1.2, H–C(1″)); 4.62 (*ddd*, ^3J = 13.2, 2.7, 1.3, H–C(3)); 4.43 (*ddd*, ^3J = 10.5, 4.5, 1.3, H–C(1′)); 4.38 (*dd*, ^3J = 5.0, 4.8, H–C(4″)); 4.25 (*ddd*, ^3J = 9.1, 4.8, 2.9, H–C(3″)); 3.35 (*s*, MeO); 3.19 (*dd*, ^2J = 16.3, ^3J = 13.2, H_{trans}–C(4)[3]); 2.80 (*dd*, ^2J = 16.3, ^3J = 2.7, H_{cis}–C(4)[3]); 2.38 (*ddd*, ^2J = 14.2, ^3J = 9.1, 5.2, H_{trans}–C(2″)[5]); 2.09 (*ddd*, ^2J = 14.2, ^3J = 2.9, 1.2, H_{cis}–C(2″)[5]); 1.82 (*ddd*, ^2J = 15.0, ^3J = 10.5, 4.6, H–C(2′)); 1.62 (*ddq*, ^3J = 12.8, 6.3, 4.6, H–C(3′)); 1.40 (*ddd*, ^2J = 15.0, ^3J = 12.8, 4.5, H–C(2′)); 0.95 (2*d*, ^3J = 6.3, 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 169.6 (*s*, arom. C); 166.6, 164.2 (2*s*, 2 CO); 162.2 (*s*, C(8)); 139.6 (*s*, C(4a)); 136.6 (*d*, ^1J(C,H) = 162, C(6)); 136.6, 133.9, 130.0 (3*d*, ^1J(C,H) = 160, arom. CH); 130.3 (*s*, arom. C); 118.3, 116.2, (2*d*, ^1J(C,H) = 160, C(5), C(7)); 108.2 (*s*, C(8a)); 105.0 (*d*, ^1J(C,H) = 168, C(1″)); 81.9 (*d*, ^1J(C,H) = 154, C(3)); 81.4 (*d*, ^1J(C,H) = 154, C(5″)); 74.4 (*d*, ^1J(C,H) = 152, C(4″)); 60.9 (*d*, ^1J(C,H) = 152, C(3″)); 55.3 (*q*, ^1J(C,H) = 141, MeO); 49.2 (*d*, ^1J(C,H) = 140, C(1′)); 40.7 (*t*, ^1J(C,H) = 130, C(4)); 38.6 (*t*, ^1J(C,H) = 140, C(2″)); 30.2 (*t*, ^1J(C,H) = 132, C(2′)); 24.6 (*d*, ^1J(C,H) = 130, C(3′)); 23.1, 21.6 (2*q*, ^1J(C,H) = 125, 2 Me–C(3′)). CI-MS (NH_3): 423 (10), 373 (41), 374 (15), 356 (23), 317 (11), 292 (11), 283 (25), 279 (19), 271 (10) 260 (13), 254 (17), 250 (18), 237 (21), 216 (36), 204 (20), 196 (17), 186 (11), 181 (18), 157 (22), 142 (31), 135 (25), 125 (17), 86 (100). Anal. calc. for $C_{28}H_{31}ClN_4O_8$ (587.03): C 57.29, H 5.32; found: C 57.25, H 5.34.

*(3S)-3,4-Dihydro-8-hydroxy-3-{(1′S)-3′-methyl-1′-{[(methyl 3″-azido-2″,3″-dideoxy-α-*D*-ribo-hexofuranosid)uronyl]amino}butyl}-1*H*-2-benzopyran-1-one* (= {*Methyl 3-Azido-2,3-dideoxy*-N-{(1′S)-1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″H-2″-benzopyran-3″-yl]-3′-methylbutyl}-α-*D*-ribo-*hexofuranosid*}*uronamide*; **23**). A mixture of (–)-**22** (20 mg, 0.034 mmol), KCN (0.5 mg), and MeOH (2 ml) was stirred at 25° for 30 min.

---

[5]) With respect to N_3–C(3″).

Evaporation and CC (silica gel, AcOEt/light petroleum ether 1:6) yielded 13.9 mg (91%). Colourless oil. IR ($CHCl_3$): 3400, 2900, 2100 (N_3), 1680, 1580, 1400, 1200, 850. ^{1}H-NMR (250 MHz, $CDCl_3$): 7.40, 6.80, 6.70 (3*m*, H–C(6), H–C(5), H–C(7)); 6.75 (*d*, ^3J = 10, NH); 5.08 (*dd*, ^3J = 5.0, 0.8, H–C(1″)); 4.80 (*ddd*, ^3J = 13.0, 3.0, 1.2, H–C(3)); 4.37 (*ddd*, ^3J = 9.5, 5.0, 1.2, H–C(1′)); 4.25 (*m*, H–C(4″), H–C(3″)); 3.40 (*d*, ^3J = 3.5, H–C(5″)); 3.17 (*s*, MeO); 3.10 (*dd*, ^2J = 16.5, ^3J = 13.0, H_{trans}–C(4)^3)); 2.84 (*dd*, ^2J = 16.5, ^3J = 3.0, H_{cis}–C(4)^3)); 2.31 (*ddd*, ^2J = 14.5, ^3J = 8.1, 5.0, H_{trans}–C(2″)^5)); 2.04 (*ddd*, ^2J = 14.5, ^3J = 2.7, 0.8, H_{cis}–C(2″)^5)); 1.87 (*ddd*, ^2J = 13.5, ^3J = 10.5, 5.0, H–C(2′)); 1.67 (*m*, H–C(3′)); 1.38 (*ddd*, ^2J = 13.5, ^3J = 9.5, 4.7 H–C(2′)); 0.92 (2*d*, 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 170.7 (*s*, C(1)); 169.4 (*s*, C(8)); 162.1 (*s*, C(6″)); 139.2 (*s*, C(4a)); 136.6 (*d*, ^1J(C,H) = 160, C(6)); 118.3 (*d*, ^1J(C,H) = 160, C(5)); 116.2 (*d*, ^1J(C,H) = 160, C(7)); 107.8 (*s*, C(8a)); 105.1 (*d*, ^1J(C,H) = 175, C(1″)); 83.7 (*d*, ^1J(C,H) = 155, C(3)); 81.1 (*d*, ^1J(C,H) = 150, C(5″)); 70.9 (*d*, ^1J(C,H) = 148, C(4″)); 60.6 (*d*, ^1J(C,H) = 148, C(3″)); 55.0 (*q*, ^1J(C,H) = 140, MeO); 49.2 (*d*, ^1J(C,H) = 137, C(1′)); 40.7 (*t*, ^1J(C,H) = 140, C(4)); 38.6 (*t*, ^1J(C,H) = 130, C(2″)); 30.3 (*t*, ^1J(C,H) = 140, C(2′)); 24.7 (*d*, ^1J(C,H) = 125, C(3′)); 23.0, 21.7 (2*q*, ^1J(C,H) = 124, 2 Me–C(3′)). CI-MS (NH_3): 448 (3, $M^{+\cdot}$), 416 (4), 374 (8), 373 (13), 356 (13), 307 (9), 279 (7), 276 (12), 254 (5), 215 (9), 198 (10), 193 (10), 186 (16), 185 (13), 182 (91), 163 (26), 141 (24), 139 (78), 115 (19), 86 (100).

*(3S)-8-Acetoxy-3,4-dihydro-3-{(1′S)-3′-methyl-1′-{[(methyl 5″-O-acetyl-3″-azido-2″,3″-dideoxy-α-*D*-ribo-hexofuranosid)uronyl]amino}butyl}-1*H*-2-benzopyran-1-one* (= {*Methyl 5-O-Acetyl-3-azido-2,3-dideoxy-*N-{*(1′S)-1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl*}-α-*D*-ribo-*hexofuranosid*}*uronamide*; (−)-**25**). A mixture of (−)-**22** (220 mg, 0.49 mmol), KCN (2 mg), and MeOH (6 ml) was stirred at 25° for 30 min. After evaporation the residue was dissolved in pyridine (3 ml) and Ac_2O (15 ml) and stirred at 45° for 15 h. The solvent was distilled off *in vacuo*, the residue taken with toluene (5 ml), and the solvent evaporated. The latter operation was repeated twice: 192 mg (96%). Colourless crystals. M.p. 68°. $[\alpha]^{25}_{589} = -146$, $[\alpha]^{25}_{578} = -147$, $[\alpha]^{25}_{546} = -159$, $[\alpha]^{25}_{436} = -271$, $[\alpha]^{25}_{365} = -496$ (c = 0.09, MeOH). IR (KBr): 3440, 2960, 2100 (N_3), 1730 (CO), 1650 (CO), 1610, 1535, 1470, 1360, 1200, 1155, 1050. ^{1}H-NMR (250 MHz, $CDCl_3$): 7.55 (*dd*, ^3J = 7.8, 7.5, H–C(6)); 7.1 (*d*, ^3J = 7.5, H–C(5)); 7.03 (*d*, ^3J = 7.8, H–C(7)); 6.23 (*d*, ^3J = 9.8, NH); 5.13 (*d*, ^3J = 3.9, H–C(5″)); 5.0 (*dd*, ^3J = 4.9, 1.2, H–C(1″)); 4.54 (*ddd*, ^3J = 12.4, 2.7, 1.0, H–C(3)); 4.37 (*ddd*, ^3J = 10.5, 4.7, 1.0, H–C(1′)); 4.25 (*m*, H–C(4″), H–C(3″)); 3.30 (*s*, MeO); 3.10 (*dd*, ^2J = 16.5, ^3J = 12.4, H_{trans}–C(4)^3)); 2.82 (*dd*, ^2J = 16.5, ^3J = 2.7, H_{cis}–C(4)^3)); 2.40 (*s*, AcO–C(8)); 2.31 (*ddd*, ^2J = 13.6, ^3J = 8.1, 4.9, H_{trans}–C(2″)^5)); 2.20 (*s*, AcO–C(5″)); 2.00 (*ddd*, ^2J = 13.6, ^3J = 2.9, 1.2, H_{cis}–C(2″)^5)); 1.87 (*ddd*, ^2J = 13.8, ^3J = 10.5, 4.8, H–C(2′)); 1.67 (*ddd*, ^3J = 9.3, 6.5, 4.8, H–C(3′)); 1.38 (*ddd*, ^2J = 13.8, ^3J = 9.3, 4.7, H–C(2′)); 0.92 (2*d*, ^3J = 6.5, 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 169.7, 169.6, 167.0, 161.7 (4*s*, 4 CO); 151.7 (*s*, C(8)); 141.3 (*s*, C(4a)); 134.7 (*d*, ^1J(C,H) = 162, C(6)); 125.4, 122.7 (2*d*, ^1J(C,H) = 162, C(5), C(7)); 117.2 (*s*, C(8a)); 105.0 (*d*, ^1J(C,H) = 170, C(1″)); 82.0 (*d*, ^1J(C,H) = 153, C(3)); 80.0 (*d*, ^1J(C,H) = 149, C(5″)); 73.8 (*d*, ^1J(C,H) = 150, C(4″)); 60.7 (*d*, ^1J(C,H) = 150, C(3″)); 55.1 (*q*, ^1J(C,H) = 140, MeO); 48.8 (*d*, ^1J(C,H) = 140, C(1′)); 40.5 (*t*, ^1J(C,H) = 125, C(4)); 38.5 (*t*, ^1J(C,H) = 136, C(2″)); 30.9 (*t*, ^1J(C,H) = 131, C(2′)); 24.4 (*d*, ^1J(C,H) = 130, C(3′)); 23.1, 21.5 (2*q*, ^1J(C,H) = 122, 2 Me–C(3′)); 21.0, 20.7 (2*q*, 2 *Me*CO). CI-MS (NH_3): 531 (1, $[M-1]^+$), 374 (7), 373 (14), 356 (22), 355 (15), 307 (7), 277 (6), 276 (6), 240 (7), 232 (6), 215 (9), 211 (13), 194 (14), 193 (100), 192 (12), 163 (10), 156 (6), 155 (6), 143 (14), 135 (15), 124 (8), 115 (7), 108 (15), 105 (6), 98 (8), 96 (6), 87 (10), 86 (72), 84 (15), 78 (9), 77 (11), 71 (13), 70 (8). Anal. calc. for $C_{25}H_{32}N_4O_9$ (532.54): C 56.38, H 6.06; found: C 56.36, H 5.97.

*(3S)-3,4-Dihydro-8-hydroxy-3-{(1′S)-3′methyl-1′-{[(methyl 3″-chloro-2″,3″-dideoxy-α-*D*-*arabino*-hexofuranosid)uronyl]amino}butyl}-1*H*-2-benzopyran-1-one* (= {*Methyl 3-Chloro-2,3-dideoxy-*N-{*(1′S)-1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl*}-α-*D*-arabino-*hexofuranosid*}*uronamide*; **26**). A mixture of (−)-**20** (15 mg, 0.026 mmol), KCN (0.5 mg), and MeOH (1.5 ml) was stirred at 25° for 30 min. Evaporation and CC (silica gel (5 g), AcOEt/light petroleum ether) yielded 10.5 mg (91%). Colourless oil. IR ($CHCl_3$): 3680, 2950, 1685, 1540, 1460, 1210, 1105, 1050, 1020, 950, 900, 810, 800. ^{1}H-NMR (250 MHz, $CDCl_3$): 10.81 (*s*, OH); 7.41 (*dd*, ^3J = 8.5, 7.5, H–C(6)); 6.90, 6.71 (2*d*, ^3J = 8.5, 7.5, H–C(5), H–C(7)); 6.78 (*d*, ^3J = 10.0, NH); 5.39 (*dd*, ^3J = 6.4, 5.9, H–C(1″)); 4.62 (*m*, H–C(3), H–C(3″)); 4.41 (*ddd*, ^3J = 10.1, 5.1, 1.5, H–C(1′)); 4.24 (*d*, ^3J = 9.3, H–C(5′)); 3.98 (*dd*, ^3J = 9.3, 2.9, H–C(4″)); 3.8 (*m*, OH); 3.42 (*s*, MeO); 3.09 (*dd*, ^2J = 16.8, ^3J = 12.8, H_{trans}–C(4)^3)); 2.85 (*dd*, ^2J = 16.8, ^3J = 3.1, H_{cis}–C(4)^3)); 2.64 (*ddd*, ^2J = 15.2, ^3J = 5.9, 0.8, H_{cis}–C(2″)^4)); 2.35 (*ddd*, ^2J = 15.2, ^3J = 6.4, 1.1, H_{trans}–C(2″)^4)); 1.82 (*ddd*, ^2J = 14.0, ^3J = 10.1, 4.7, H–C(2′)); 1.64 (*ddq*, ^3J = 13.2, 6.5, 4.7, H–C(3′)); 1.40 (*ddd*, ^2J = 14.0, ^3J = 13.2, 5.1, H–C(2′)); 0.95 (2*d*, ^3J = 6.5, 2 Me–C(3′)). CI-MS (NH_3): 442 (4, $[M+1]^+$), 401 (24), 37 (4), 350 (5), 340 (34), 293 (6), 288 (42), 284 (28), 251 (9), 244 (11), 235 (17), 213 (26), 212 (27), 193 (29), 182 (63), 163 (100).

*(3S)-3-{(1′S)-1′-{[(5″-O-Acetyl-3″-azido-2″,3″-dideoxy-α-*D*-ribo-hexaro-1″,4″-lactone)-6″-oyl]amino}-3′-methylbutyl}-3,4-dihydro-8-hydroxy-1*H*-2-benzopyran-1-one* (= {*2-O-Acetyl-4-azido-4,5-dideoxy-*N-{*(1′S)-1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl*}-α-*D*-ribo-*hexaro-6,3-lactone*}-

1-amic Acid; (−)-**27**)[6]). The 3-$ClC_6H_4CO_3H$ (85%; 100 mg, 0.45 mmol) was added portionwise to a stirred soln. of (−)-**25** (80 mg, 0.15 mmol) in anh. CH_2Cl_2 (0.3 ml). After the addition of $BF_3 \cdot Et_2O$ (10 µl), the mixture was stirred at 25° for 5 h (TLC control, AcOEt/light petroleum 1:1). Evaporation and CC (silica gel (5 g), AcOEt/light petroleum ether) yielded 48 mg (66%). Unstable colourless oil. $[\alpha]_{589}^{25} = -65$, $[\alpha]_{578}^{25} = -87$, $[\alpha]_{546}^{25} = -88$, $[\alpha]_{436}^{25} = -121$, $[\alpha]_{365}^{25} = -187$, ($c$ = 0.6, CH_2Cl_2). ^{1}H-NMR (250 MHz, $CDCl_3$): 10.72 (*s*, OH); 7.43 (*dd*, ^3J = 8.3, 7.5, H–C(6)); 6.90 (*d*, ^3J = 8.3, H–C(7)); 6.71 (*d*, ^3J = 7.5, H–C(5)); 6.4 (*d*, ^3J = 9.8, NH); 5.4 (*d*, ^3J = 2.5, H–C(5″)); 4.80 (*ddd*, ^3J = 8.8, 4.8, 4.3, H–C(3″)); 4.61 (*dd*, ^3J = 4.3, 2.5, H–C(4″)); 4.59 (*ddd*, ^3J = 13.0, 3.2, 1.1, H–C(3)); 4.38 (*ddd*, ^3J = 10.5, 4.0, 1.1, H–C(1′)); 3.10 (*dd*, ^2J = 18.5, ^3J = 8.8, H_{trans}–C(2″)[5])); 3.00 (*dd*, ^2J = 16.8, ^3J = 13.0, H_{trans}–C(4)[3])); 2.85 (*dd*, ^2J = 16.8, ^3J = 3.2, H_{cis}–C(4)[3])); 2.55 (*dd*, ^2J = 18.5, ^3J = 4.8, H_{cis}–C(2″)[5])); 2.19 (*s*, Ac); 1.94 (*ddd*, ^2J = 13.5, ^3J = 10.5, 4.5, H–C(2′)); 1.62 (*ddd*, ^3J = 9.2, 6.6, 4.6, H–C(3′)); 1.42 (*ddd*, ^2J = 13.5, ^3J = 9.2, 4.0, H–C(2′)); 0.96 (2*d*, ^3J = 6.6, 2 Me–C(3′)[6])). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 173.0 (*s*, C(1″)); 169.0 (*s*, C(1)); 165.0, 163.8 (2*s*, 2 CO); 162.1 (*s*, C(8)); 139.3 (*s*, C(4a)); 136.7 (*d*, arom. CH); 135.2 (*s*, arom. C); 134.5 (*d*, ^1J(C,H) = 162, C(6)); 130.3, 129.9, 127.8 (3*d*, arom. CH); 129.5 (*s*, arom. C); 118.4, 116.2 (2*d*, ^1J(C,H) = 163, 162, C(5), C(7)); 108.1 (*s*, C(8a)); 83.0 (*d*, ^1J(C,H) = 158, C(3)); 80.0 (*d*, ^1J(C,H) = 148, C(5″)); 73.8 (*d*, ^1J(C,H) = 149, C(4″)); 57.7 (*d*, ^1J(C,H) = 151, C(3″)); 49.4 (*d*, ^1J(C,H) = 139, C(1′)); 40.5 (*t*, ^1J(C,H) = 120, C(4)); 35.0 (*t*, ^1J(C,H) = 138, C(2″)); 30.1 (*t*, ^1J(C,H) = 130, C(2′)); 25.0, (*d*, ^1J(C,H) = 130, C(3′)); 25.0–20.0 (3*q*, ^1J(C,H) ≈ 122, 2 Me–C(3′), 2 *Me*CO).

*(3S)-3-{(1′S)-1′-{[(3″-Azido-5″-O-(3-chlorobenzoyl)-2″,3″-dideoxy-α-*D*-ribo-hexaro-1″,4″-lactone)-6″-oyl]-amino}-3′-methylbutyl}-3,4-dihydro-8-hydroxy-1*H*-2-benzopyran-1-one* (= {*4-Azido-2-O-(3-chlorobenzoyl)-4,5-dideoxy*-N-{(*1′S*)-*1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H-*2″-benzopyran-3″-yl]-3′-methylbutyl*}-α-D-ribo-*hexaro-6,3-lactone*}-*1-amic Acid*; (−)-**28**)[6]). Prepared by the above procedure from (−)-**22**. (−)-**28**: M.p. 91°. $[\alpha]_{589}^{25} = -66$, $[\alpha]_{578}^{25} = -71$, $[\alpha]_{546}^{25} = -93$, $[\alpha]_{436}^{25} = -222$, $[\alpha]_{365}^{25} = -512$ (c = 0.09, MeOH). IR (KBr): 3415 (OH), 2960, 2100 (N_3), 1790, 1730, 1670, 1620 (CO), 1530, 1460, 1285, 1240, 1160, 1110, 1045. ^{1}H-NMR (250 MHz, $CDCl_3$): 10.7 (*s*, OH); 7.98, 7.89, 7.64, 7.47 (4 H, arom. CH); 7.47 (*dd*, ^3J = 8.5, 7.5, H–C(6)); 6.90 (*d*, ^3J = 8.5, H, H–C(5)); 6.75 (*d*, ^3J = 7.5, H–C(7)); 6.5 (*d*, ^3J = 10.0, NH); 5.66 (*d*, ^3J = 2.1, H–C(5″)); 4.97 (*ddd*, ^3J = 8.5, 4.7, 4.2, H–C(3″)); 4.69 (*dd*, ^3J = 4.2, 2.2, H–C(4″)); 4.61 (*ddd*, ^3J = 12.5, 2.8, 2.2, H–C(3)); 4.40 (*ddd*, ^3J = 10.5, 4.8, 2.2, H–C(1′)); 3.18 (*dd*, ^2J = 18.0, ^3J = 8.5, H_{trans}–C(2″)[5])); 3.15 (*dd*, ^2J = 16.5, ^3J = 12.5, H_{trans}–C(4)[3])); 2.80 (*dd*, ^2J = 16.5, ^3J = 2.8, H_{cis}–C(4)[3])); 2.64 (*dd*, ^2J = 18.0, ^3J = 4.7, H_{cis}–C(2″)[5])); 1.81 (*ddd*, ^2J = 13.5, ^3J = 10.5, 4.8, H–C(2′)); 1.60 (*ddd*, ^3J = 9.0, 6.5, 4.8, H–C(3)); 1.47 (*ddd*, ^2J = 13.5, ^3J = 9.0, 4.8, H–C(2′)); 0.93 (2*d*, ^3J = 6.5, 2 Me–C(3′))[6]). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 172.7 (*s*, C(1″)); 169.4 (*s* C(1)); 165.7, 163.9, (2*s*, 2 CO); 162.1 (*s*, C(8)); 139.2 (*s*, C(4a)); 136.7 (*d*, arom. CH); 135.1 (*s*, arom. C); 134.4 (*d*, ^1J(C,H) = 162, C(6)); 130.2, 129.9, 127.8 (3*d*, arom. CH); 129.7 (*s*, arom. C); 118.4, 116.2 (2*d*, ^1J(C,H) = 166, 164, C(5), C(7)); 107.8 (*s*, C(8a)); 83.4 (*d*, ^1J(C,H) = 160, C(3)); 80.9 (*d*, ^1J(C,H) = 148, C(5″)); 73.8 (*d*, ^1J(C,H) = 149 C(4″)); 57.7 (*d*, ^1J(C,H) = 153, C(3″)); 49.4 (*d*, ^1J(C,H) = 137, C(1′)); 40.5 (*t*, ^1J(C,H) = 124, C(4)); 34.7 (*t*, ^1J(C,H) = 135, C(2″)); 30.1 (*t*, ^1J(C,H) = 133, C(2′)); 24.7 (*d*, ^1J(C,H) = 130, C(3′)); 23.0, 21.7 (2*q*, ^1J(C,H) = 122, 2 Me–C(3′)). CI-MS (NH_3): 590 (3, $[M + 2 + 18]^+$), 589 (5, $[M + 1 + 18]^+$), 588 (5, $[M + 18]^+$), 575 (7), 574 (21), 573 (37), 572 (57, $[M + 1]^+$), 571 (53, M^+), 570 (7), 553 (5), 552 (4), 407 (6), 372 (3), 252 (20), 231 (18), 230 (23), 225 (14), 224 (10), 210 (15), 209 (20), 198 (20), 197 (31), 163 (12), 156 (21), 141 (31), 139 (100), 135 (13), 111 (21), 93 (15), 86 (34), 84 (21), 77 (15), 75 (11), 71 (14), 70 (10). Anal. calc. for $C_{27}H_{27}ClN_4O_8$ (570.99): *C* 56.79, *H* 4.77; *found*: *C* 56.78, *H* 4.87.

*(3S)-3-{(1′S)-1′-{[(3″-Amino-5″-O-(3-chlorobenzoyl)-2″,3″-dideoxy-α-*D*-ribo-hexaro-1″,4″-lactone)-6″-oyl]amino}-3′-methylbutyl}-3,4-dihydro-8-hydroxy-1*H*-benzopyran-1-one* (= {*4-Amino-2-O-(3-chlorobenzoyl)-4,5-dideoxy*-N-{(*1′S*)-*1′-[(3″S)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H-*2″-benzopyran-3″-yl]-3′-methylbutyl*}-α-D-ribo-*hexaro-6,3-lactone*}-*1-amic Acid*; (−)-**29**). A soln. of (−)-**28** (110 mg, 0.19 mmol) in anh. benzene was degassed by a flow of Ar for 30 min under boiling. Bu_3SnH (281 µl, 0.96 mmol) and 2,2′-azobis(isobutyronitrile) (= 2,2′-dimethyl-2,2′-azobis[propanenitrile]; AIBN; 5 mg) were added, and the mixture was heated under reflux for 1 h (TLC, AcOEt/light petroleum ether *1*:3, R_f 0.3 ((−)-**28**), and O ((−)-**29**); R_f (CH_2Cl_2/MeOH *20*:*1*) *0.1* ((−)-**29**)). After evaporation $CHCl_3$ (7 ml) and H_2O (5 ml) were added, and the mixture was vigourously stirred at 25° for 30 min. The org. layer was collected, the aq. phase extracted with $CHCl_3$ (50 ml, 3 times), the combined org. extract dried ($MgSO_4$) and evaporated, and the residue purified by CC (silica gel (7 g); CH_2Cl_2, then CH_2Cl_2/MeOH 19:1): 100 mg (96%) of (−)-**29** that were recrystallized from $CHCl_3$/hexane. M.p. 104–106°. $[\alpha]_{589}^{25} = -69$, $[\alpha]_{578}^{25} = -98$, $[\alpha]_{546}^{25} = -109$, $[\alpha]_{436}^{25} = -106$, $[\alpha]_{365}^{25} = -168$ (c = 0.11, MeOH): IR ($CHCl_3$): 3400, 2980, 1790, 1730, 1680, 1620,

---

[6]) For commodity reasons, the numbering of the corresponding (methyl hexofuranosid)uronic acid is employed here.

1535, 1460, 1230, 1210, 1110, 810. ^{1}H-NMR (250 MHz, $CDCl_3$): 7.88, 7.82, 7.58, 7.40 (4 H, arom. CH); 7.40 (*dd*, ^3J = 8.5, 7.5, H–C(6)); 6.87 (*d*, ^3J = 7.5, H–C(7)); 6.70 (*d*, ^3J = 8.5, H–C(5)); 5.63 (*d*, ^3J = 2.5, H–C(5″)); 4.60 (*ddd*, ^3J = 12.4, 2.6, 2.1, H–C(3)); 4.50 (*dd*, ^3J = 5.5, 2.5, H–C(4″)); 4.37 (*ddd*, ^3J = 9.8, 4.5, 2.1, H–C(1′)); 4.13 (*ddd*, ^3J = 8.4, 6.8, 5.5, H–C(3″)); 3.18 (*dd*, ^2J = 16.5, ^3J = 12.4, H_{trans}–C(4)[3]); 3.00 (*dd*, ^2J = 18.0, ^3J = 8.4, H_{trans}–C(2″)[7]); 2.80 (*dd*, ^2J = 16.5, ^3J = 2.6, H_{cis}–C(4)[3]); 2.40 (*dd*, ^2J = 18.0, ^3J = 6.8, H_{cis}–C(2″)[7]); 1.92 (*ddd*, ^2J = 13.7, ^3J = 9.8, 4.8, H–C(2′)); 1.68 (*ddd*, ^3J = 9.3, 6.5, 4.8, H–C(3′)); 1.49 (*ddd*, ^2J = 13.7, ^3J = 9.3, 4.5, H–C(2′)); 0.93 (2*d*, ^3J = 6.5, 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 174.2 (*s*, C(1″)); 169.4 (*s*, C(1)); 166.2, 164,0 (2*s*, 2 CO); 162.0 (*s*, C(8)); 139.4, (*s*, C(4a)); 136.6 (*d*, arom. CH); 134.9 (*s*, arom. C); 134.2 (*d*, ^1J(C,H) = 160, C(6)); 130.1, 129.8, 127.8 (3*d*, arom CH); 128.8 (*s*, arom. C); 118.4, 116.1 (2*d*, ^1J(C,H) = 165, 163, C(5), C(7)); 107.9 (*s*, C(8a)); 86.3 (*d*, ^1J(C,H) = 155, C(3)); 81.0 (*d*, ^1J(C,H) = 156, C(5″)); 74.8 (*d*, ^1J(C,H) = 152, C(4″)); 49.4 (*d*, ^1J(C,H) = 143, C(3″)); 49.3 (*d*, ^1J(C,H) = 138, C(1′)); 40.3 (*t*, ^1J(C,H) = 127, C(4)); 38.0 (*t*, ^1J(C,H) = 136, C(2″)); 30.1 (*t*, ^1J(C,H) = 132, C(2′)); 24.6 (*d*, ^1J(C,H) = 123, C(3′)); 23.0, 21.6 (2*q*, ^1J(C,H) = 124, 2 Me–C(3′)). CI-MS (NH_3): 545 (8, $M^{+\cdot}$), 408 (4), 382 (5), 339 (7), 282 (4), 275 (12), 273 (4), 269 (7), 268 (5), 259 (5), 258 (6), 244 (5), 232 (6), 230 (12), 227 (5), 201 (8), 197 (3), 188 (3), 176 (5), 172 (16), 170 (30), 163 (11), 156 (143), 155 (13), 145 (9), 141 (30), 140 (13), 139 (100), 111 (38), 86 (79). Anal. calc. for $C_{27}H_{29}ClN_2O_8$ (545.01): C 59.47, H 5.32; found: C 59.6, H 5.13.

*(3*S*)-3-{(1′*S*)-1′-[(3″-Amino-2″,3″-dideoxy-*α*-*D*-ribo-hexar-6″-oyl)amino]-3′-methylbutyl}-3,4-dihydro-8-hydroxy-1*H*-2-benzopyran-1-one* (= *{4-Amino-4,5-dideoxy-*N*-{(1′*S*)-1′-[(3″*S*)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl}-α-*D*-ribo-hexar-1-amic Acid*; AI-77-B; (−)-**1**). At 25°, 0.1N NaOH was added dropwise to a stirred suspension of (−)-**29** (24 mg, 0.44 mmol) in MeOH/H_2O 1:1 so as to maintain the pH at *ca.* 11 (TLC control, silica gel, BuOH/H_2O/AcOH/pyridine 4:2:1:1, R_f 0.2 ((−)-**1**). After the end of the reaction (*ca.* 6 h), the pH was adjusted to 6.5 with 0.1N HCl. After 1 h stirring at 25°, the mixture was poured onto a column of *Amberlite XAD-2* (20 ml) previously treated with H_2O. After washing the column with H_2O/MeOH 4:1 (100 ml), the products were eluted with H_2O/MeOH 1:4: 12 mg (65%) of (−)-**1** which was recystallized from MeCN/MeOH at −25°. M.p. 130° (dec.; [4b]: 139–140°). $[\alpha]_{589}^{25} = -71$, $[\alpha]_{578}^{25} = -76$, $[\alpha]_{546}^{25} = -72$, $[\alpha]_{436}^{25} = -104$, $[\alpha]_{365}^{25} = -240$ (*c* = 0.28, MeOH; [4b]: $[\alpha]_D^{22} = -78.2$ (*c* = 0.08, MeOH)). IR (THF): 3570, 3500, 2800, 1800, 1680, 1630, 1590, 1520, 1000. ^{1}H-NMR (250 MHz, CD_3CN): 7.50 (*dd*, ^3J = 8.3, 8.1, H–C(6)); 7.4 (*d*, ^3J = 10.0, NH); 6.87, 6.83 (2*d*, ^3J = 8.3, 8.1, H–C(5), H–C(7)); 5.04 (*dd*, ^3J = 2.5, 2.3, H–C(4″)); 4.57 (*ddd*, ^3J = 8.5, 7.9, 4.3, H–C(3)); 4.50 (*d*, ^3J = 2.3, H–C(5″)); 4.30 (*ddd*, ^3J = 9.0, 2.8, 2.5, H–C(3″)); 4.20 (*m*, H–C(1′)); 3.08 (*dd*, ^2J = 16.5, ^3J = 4.3, H_{cis}–C(4)[3]); 3.04 (*dd*, ^2J = 18.8, ^3J = 9.0, H–C(2″)); 3.03 (*dd*, ^2J = 16.5, ^3J = 8.5, H_{trans}–C(4)[3]); 2.72 (*dd*, ^2J = 18.8, ^3J = 2.8, H–C(2″)); 1.61 (*m*, H–C(3′), H–C(2′)); 1.33 (*ddd*, ^2J = 14.5, ^3J = 11.0, 4.5, H–C(2′)); 0.92 (2*d*, ^3J = 6.3, 2 Me–C(3′)[6]). ^{13}C-NMR (62.9 MHz, CD_3CN): 173.9 (*s*, C(1″)); 170.5 (*s*, C(1)); 170.7 (*s*, C(8)); 161.8 (*s*, C(6″)); 139.6 (*s*, C(4a)); 137.2 (*d*, ^1J(C,H) = 160, C(6)); 119.1, 116.0 (2*d*, ^1J(C,H) = 155, 160, C(5), C(7)); 108.8 (*s*, C(8a)); 82.7 (*d*, ^1J(C,H) = 155, C(3)); 82.0 (*d*, ^1J(C,H) = 152, C(5″)); 72.1 (*d*, ^1J(C,H) = 148, C(4″)); 49.0 (*d*, ^1J(C,H) = 139, C(3″)); 48.4 (*d*, ^1J(C,H) = 155, C(1′)); 38.6 (*t*, ^1J(C,H) = 125, C(4)); 33.7 (*t*, ^1J(C,H) = 137, C(2″)); 29.3 (*t*, ^1J(C,H) = 130, C(2′)); 24.6 (*d*, ^1J(C,H) = 135, C(3′)); 22.9, 20.7 (2*q*, 2 Me–C(3′)[6]). CI-MS (NH_3): 432 (4, $[M + 18]^+$), 425 (3, $[M + 1]^+$), 407 (10), 390 (10), 384 (5), 341 (4), 320 (11), 308 (3), 306 (4), 275 (15), 244 (12), 233 (15), 230 (20), 227 (17), 214 (35), 199 (23), 188 (30), 86 (100).

*(3*S*)-3-{(1′*S*)-1′-{{3″-[(-Chlorobenzoyl)amino]-2″,3″-dideoxy-α-D-ribo-hexar-6″-oyl}amino}-3′-methylbutyl-3,4-dihydro-8-hydroxy-1*H*-2-benzopyran-1-one* (= *4-[(3-Chlorobenzoyl)amino]-4,5-dideoxy-*N*-{(1′*S*)-1′-[(3″*S*)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl}-α-*D*-ribo-hexar-1-amic Acid*; **30**)[6]). When MeOH/H_2O 1:1 was replaced by EtOH/H_2O 1:1 in the above procedure, a 1:1 mixture (−)-**1**/**30** was obtained. These two compounds were separated and purified by reversed-phase HPLC (column *Protein and Peptide Separation Vidac C18*, No. *218TP1022*, λ 214 nm, Me_3CN/H_2O; MeCN 30%, 40 min→MeCN 80%, 5 min→MeCN 100%).

Characteristics of **30**: IR ($CHCl_3$): 3600, 2900, 1780, 1670, 1570, 1530, 1460, 1200, 1110. ^{1}H-NMR (250 MHz, CD_3CN): 7.7–7.3 (*m*, arom. CH); 7.30 (*dd*, ^3J = 8.5, 7.7, H–C(6)); 7.1 (*d*, ^3J = 9.5, NH); 6.80, 6.65 (2*d*, ^3J = 8.5, 7.7, H–C(5), H–C(7)); 4.84 (*dd*, ^3J = 2.4, 2.1, H–C(4″)); 4.71 (*m*, H–C(3)); 4.62 (*ddd*, ^3J = 9.1, 3.8, 2.4, H–C(3″)); 4.45 (*d*, ^3J = 2.1, H–C(5″)); 4.22 (*m*, H–C(1′)); 2.95 (*dd*, ^2J = 18.5, ^3J = 9.1, H–C(2″)); 2.88 (*dd*, ^2J = 16.6, ^3J = 11.5, H_{trans}–C(4)[3]); 2.82 (*dd*, ^2J = 16.5, ^3J = 3.5, H_{cis}–C(4)[3]); 2.50 (*dd*, ^2J = 18.5, ^3J = 3.8, H–C(2″)); 1.63 (*m*, H–C(3′), H–C(2′)); 1.27 (*ddd*, ^3J = 13.2, 8.7, 4.5, H–C(2′)); 0.90, 0.80 (2*d*, ^3J = 6.5, 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 174.0, 168.9, 167.1, 163.3, (4*s*, 4 CO); 162.0 (*s*, C(8)); 138.7 (*s*, C(4a)); 136.8 (*d*, arom. CH); 134.7 (*s*, arom. C); 132.0 (*d*, ^1J(C,H) = 160, C(6)); 129.8, 129.7, 127.5 (3*d*, arom. CH); 125.0

---

[7]) With respect to NH_2–C(3).

(*s*, arom. C); 118.4, 116.4 (2*d*, ^1J(C,H) = 165, 163, C(5), C(7)); 107.6 (*s*, C(8a)); 85.6 (*d*, ^1J(C,H) = 155, C(3)); 80.6 (*d*, ^1J(C,H) = 156, C(5″)); 49.8 (*d*, ^1J(C,H) = 143, C(3″)); 47.3 (*d*, ^1J(C,H) = 138, C(1′)); 39.7 (*t*, ^1J(C,H) = 127, C(4)); 36.4 (*t*, ^1J(C,H) = 136, C(2″)); 30.1 (*t*, ^1J(C,H) = 132, C(2″)); 24.6 (*d*, ^1J(C,H) = 123, C(3′)); 23.0, 21.5 (2*q*, ^1J(C,H) = 124, 2 Me–C(3′)).

*Methyl (Methyl 3-Azido-5-*O*-(3-chlorobenzoyl)-2,3-dideoxy-*α*-*DL*-*ribo*-hexofuranosid)uronate* ((±)-**31**). A mixture of (±)-**19** (100 mg, 0.28 mmol), CsN_3 (240 mg, 1.37 mmol), and anh. DMF (5 ml) was heated to 120° under Ar for 20 h. After cooling to 20°, Et_2O (10 ml) was added and the soln. washed with H_2O (10 ml, twice) and dried ($MgSO_4$). Evaporation and CC (silica gel (5 g), AcOEt/light petroleum ether 1:4) yielded 71.3 mg (69%). Colourless oil. IR (CH_2Cl_2): 2960, 2930, 2100, 1735, 1570, 1430, 1240, 1125, 1105, 1045, 890. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.05, 7.95, 7.60, 7.44 (4 H, arom. CH); 5.57 (*d*, ^3J = 2.9, H–C(5)); 5.14 (*dd*, ^3J = 5.0, 1.0, H–C(1)); 4.49 (*dd*, ^3J = 4.5, 2.9, H–C(4)); 4.25 (*ddd*, 9.0, 4.5, 2.7, H–C(3)); 3.85 (*s*, CO_2Me); 3.40 (*s*, MeO); 2.42 (*ddd*, ^2J = 14.3, ^3J = 9.0, 5.0, H–C(2) *trans* to N_3); 2.13 (*ddd*, ^2J = 14.3, ^3J = 2.7, 1.0, H–C(2) *cis* to N_3). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 167.7, 164.3 (2*s*, 2 CO); 134.9, 133.6, 130.4, 130.0, 129.9, 127.7 (6 arom. C); 104.9 (*d*, ^1J(C,H) = 171, C(1)); 81.8 (*d*, ^1J(C,H) = 152, C(5)); 72.5 (*d*, ^1J(C,H) = 152, C(4)); 60.0 (*d*, ^1J(C,H) = 153, C(3)); 55.3 (*q*, MeO); 52.5 (*q*, CO_2Me); 39.0 (*t*, ^1J(C,H) = 133, C(2)). EI-MS (70 eV): 266 (9), 232 (11), 217 (9), 200 (13), 185 (26), 142 (58), 105 (55.5), 91 (100). Anal. calc. for $C_{15}H_{16}ClN_3O_6$ (369.76): C 48.72, H 4.36, N 11.36; found: C 48.36, H 4.01, N 11.29.

(±)-5-Bromo-7-oxabicyclo[2.2.1]hept-5-en-2-one ((±)-**34**). A soln. of benzeneselenenyl bromide (96% pure; 40 g, 0.17 mol) in CH_2Cl_2 (300 ml) was added slowly to a soln. of *Diels-Alder* adducts **8** of furan to 1-cyanovinyl acetate (30 g, 0.17 mol) in MeCN (100 ml). After staying at 20° for 7 days, the solvent was evaporated and the residue dissolved in THF (400 ml). After cooling to 0°, 30% aq. H_2O_2 soln. (160 ml, 1.6 mol) was added slowly under stirring. After 4 h stirring at 20°, the soln. was cooled to 0° and sodium pyrosulfite ($Na_2S_2O_5$; 200 g, 1.05 mol) added portionwise (dec. of excess $H_2O_2 \rightarrow Na_2SO_4$ precipitate). When the KI test was negative, the temp. was allowed to reach 20°, and KOH/H_2O (200 ml) was added (pH 9). After stirring at 20° for 30 min, formaline (37% H_2CO in H_2O; 130 ml, 1.7 mol) was added and the mixture stirred for 1 h. The org. layer was collected and the aq. phase extracted with Et_2O (300 ml, twice), then with CH_2Cl (300 ml, 3 times). The combined org. extracts were washed with 2N HCl (100 ml) and then with brine (300 ml, 3 times). The solvent was distilled off under reflux (*Vigreux* column). The residue was filtered though a pad of silica gel (300 g, CH_2Cl_2): 23 g (76%). Yellow oil. IR ($CHCl_3$): 1770, 1580, 1275, 1120, 910, 823. ^{1}H-NMR (250 MHz, $CDCl_3$): 6.44 (*d*, ^3J = 2.4, H–C(6)); 5.07 (*d*, ^3J = 4.2, H–C(4)); 4.55 (*d*, ^3J = 2.4, H–C(1)); 2.37 (*dd*, ^2J = 17.0, ^3J = 4.2, H_{exo}–C(3)); 2.16 (*d*, ^2J = 17.0, H_{endo}–C(3)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 203.9 (*s*, C(2)); 132.7 (*s*, C(5)); 128.1 (*d*, ^1J(C,H) = 179, C(6)); 83.7, 83.3 (2*d*, ^1J(C,H) = 175, C(4), C(1)); 32.5 (*t*, ^1J(C,H) = 141.5, C(3)). EI-MS (70 eV): 188 (1, M^+), 148 (94), 146 (100), 118 (10), 81 (16), 53 (46), 52 (22), 51 (39), 50 (27). Anal. calc. for $C_6H_5BrO_2$ (189.01): C 38.13, H 2.67; found: C 38.16, H 2.74.

(±)-5-Bromo-7-oxabicyclo[2.2.1]heptan-2-one ((±)-**35**). A soln. of (±)-**34** (2 g, 10.05 mmol) in anh. dioxane (10 ml) was added to a vigourously stirred suspension of potassium azodicarboxylate (5 g, 25 mmol) in anh. dioxane (100 ml) under Ar. AcOH (10 ml) was then added dropwise in *ca.* 1 h (N_2 evolution, yellow→white, precipitate; TLC control, AcOEt/light petroleum ether 1:12, detection with 2,4-dinitrophenylhydrazine). After the end of the reduction (*ca.* 3 h), the precipitate was filtered off and washed with $CHCl_3$ (50 ml). The filtrate was treated with 2N HCl (120 ml) and stirred at 20° for 12 h. The org. layer was washed with a sat. aq. $NaHCO_3$ soln. (50 ml, 3 times), H_2O (50 ml), and brine (30 ml, 3 times). After drying ($MgSO_4$), the solvent was distilled off under reflux (*Vigreux* column) and the residue purified by filtration on a short column of silica gel (CH_2Cl_2): 1.75 g (87%). Yellowish oil. IR ($CHCl_3$): 3000, 1670, 1430, 1395, 1270, 1260, 1220, 1160, 1000, 940. ^{1}H-NMR (250 MHz, $CDCl_3$): 4.88 (*dd*, ^3J = 5.8, 5.5, H–C(4)); 4.33 (*d*, ^3J = 6.5, H–C(1)); 4.20 (*dddd*, ^3J = 10.5, 5.5, 4.0, ^4J(5,3*exo*) = 1.2, H–C(5)); 2.95 (*d*, ^2J = 18.0, H_{endo}–C(3)); 2.60 (*ddd*, ^2J = 14.6, ^3J = 10.5, 6.5, H_{exo}–C(6)); 2.42 (*ddd*, ^2J = 18.0, ^3J = 5.8, ^4J = 1.2, H_{exo}–C(3)); 1.76 (*dd*, ^2J = 14.6, ^3J = 4.0, H_{endo}–C(6)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 208.5 (*s*, C(2)); 80.3 (*d*, ^1J(C,H) = 168, C(1)); 78.0 (*d*, ^1J(C,H) = 165, C(4)); 42.9 (*d*, ^1J(C,H) = 165, C(5)); 40.0 (*t*, ^1J(C,H) = 135, C(3)); 36.2 (*t*, ^1J(C,H) = 135, C(6)). EI-MS (70 eV): 192 (8, $[M + 1]^+$), 190 (8, M^+), 111 (24), 83 (85), 55 (100), 54 (12), 53 (21). Anal. calc. for $C_6H_7BrO_2$ (191.02): C 37.72, H 3.69; found: C 37.37, H 3.59.

*(±)-5-*exo*-Azido-7-oxabicyclo[2.2.1]heptan-2-one* ((±)-**36**). A mixture of (±)-**35** (5 g, 26.2 mmol), NaN_3 (8.5 g, 131 mmol), and anh. DMF (50 ml) was heated to 110° for 20 h (TLC, AcOEt/light petroleum ether 1:6). The solvent was evaporated, the residue taken in Et_2O (200 ml), the soln. washed with H_2O (50 ml, 5 times) and brine (50 ml), dried ($MgSO_4$), and evaporated, and the residue purified by filtration on a short column of silica gel (110 g, AcOEt/light petroleum ether 1:6): 2.38 g (66%). Colourless crystals. M.p. 30°. UV (95% EtOH): 210 (1250). IR (KBr): 2940, 2100, 1770, 1440, 1405, 1350, 1250, 1165, 1145, 1010, 940, 875, 785. ^{1}H-NMR (250 MHz, $CDCl_3$): 4.88 (br. *d*, ^3J = 6.4, ^4J = 1.3, H–C(4)); 4.48 (br. *d*, ^3J = 6.2, ^4J = 1.0, H–C(1)); 3.78 (*ddd*, ^3J = 7.3, 3.3, ^4J = 1.0, H–C(5)); 2.53 (*ddd*, ^2J = 17.8, ^3J = 6.4, ^4J = 1.3, H_{exo}–C(3)); 2.20 (*dd*, ^2J = 14.0, ^3J = 7.3, H_{endo}–C(6)); 2.08 (*ddd*,

^2J = 14.0, ^3J = 6.2, 3.3, H_{exo}–C(6)); 2.02 (br. *d*, ^3J = 17.8, H_{endo}–C(3)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 208.7 (*s*, C(2)); 81.1 (*d*, ^1J(C,H) = 165, C(1)); 78.9 (*d*, ^1J(C,H) = 163, C(4)); 61.5 (*d*, ^1J(C,H) = 150, C(5)); 40.3, 32.5 (2*t*, ^1J(C,H) = 140, 135, C(3), C(6)). EI-MS (70 eV): 153 (10, $[M + 1]^+$), 149 (8), 128 (7), 125 (12), 111 (15), 97 (9), 70 (12), 69 (80), 68 (16), 55 (100), 54 (65). Anal. calc. for $C_6H_7N_3O_2$ (153.00): C 47.05, H 4.61; found: C 47.05, H 4.79.

*(±)-5-*exo*-Azido-2-{[(*tert*-butyl)dimethylsilyl]oxy}-7-oxabicyclo[2.2.1]hept-2-ene* ((±)-**37**). In a *Schlenk* tube (magnetic bar), KH (903 mg, 22.52 mmol) and anh. THF (20 ml) under Ar were cooled to 0°. $(Me_3Si)_2$NH (4.5 ml, 22.52 mmol) was added and the mixture stirred at 25° for 45 min (end of H_2 evolution). After cooling to −78°, a soln. of (±)-**36** (1.15 g, 7.5 mmol) and (*t*-Bu)Me_2SiCl (3.4 g, 22.52 mmol) in anh. THF (18 ml) was added dropwise. After 30 min, the soln. was poured into 5% aq. NH_4Cl soln. (100 ml) cooled to 0°. The mixture was extracted with Et_2O (50 ml, 3 times), the combined org. extract washed with H_2O (50 ml) and brine (50 ml) and evaporated, and the brownish residue purified by CC (silica gel (80 g), AcOEt/light petroleum ether 1:15): 1.7 g (85%). Pale yellow oil. IR ($CHCl_3$): 3010, 2960, 2940, 2845, 2090, 1775, 1660, 1485, 1340, 1165, 870, 840. ^{1}H-NMR (250 MHz, $CDCl_3$): 4.85 (*s*, H–C(3)); 4.84 (*s*, H–C(4)); 4.54 (*d*, ^3J = 4.5, H–C(1)); 3.52 (*dd*, ^3J = 6.9, 2.1, H–C(5)); 1.99 (*dd*, 12.1, ^3J = 6.9, H_{endo}–C(6)); 1.79 (*ddd*, ^2J = 12.1, ^3J = 4.5, 2.1, H_{exo}–C(6)); 0.80 (*s*, *t*-Bu); 0.20, 0.14 (2*s*, Me_2Si). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 165.1 (*s*, C(2)); 100.5 (*d*, ^1J(C,H) = 171, C(3)); 83.9 (*d*, ^1J(C,H) = 166, C(1)); 78.4 (*d*, ^1J(C,H) = 162, C(4)); 61.5 (*d*, ^1J(C,H) = 150.6, C(5)); 32.5 (*t*, ^1J(C,H) = 135, C(6)); 25.5 (*q*, ^1J(C,H) = 124, *t*-Bu); 0.5, 0.4 (2*q*, ^1J(C,H) = 125, 2 Me). EI-MS (70 eV): 212 (3), 211 (5), 182 (20), 156 (16), 155 (100), 141 (15), 125 (16), 111 (10), 85 (16), 81 (14), 75 (28), 73 (63), 69 (18), 59 (30), 67 (20), 55 (40), 54 (14). Anal. calc. for $C_{12}H_{21}N_3O_2Si$ (267.41): C 53.89, H 7.92; found: C 52.76, H 7.44.

*(1RS,2RS,3RS,4SR,5RS)-6-*exo*-Azido-3-*endo*-{[(*tert*-butyl)dimethylsilyl]oxy}-3-*exo*-hydroxy-7-oxabicyclo[2.2.1]hept-2-*exo*-yl 3-Chlorobenzoate* ((±)-**38a**) *and (1RS,2RS,3SR,4SR,5SR)-5-*exo*-Azido-2-*endo*-{[(*tert*-butyl)dimethylsilyl]oxy}-3-*exo*-hydroxy-7-oxabicyclo[2.2.1]hept-2-*exo*-yl 3-Chlorobenzoate* ((±)-**38b**). The 3-$ClC_6H_4CO_3H$ (85%; 800 mg, 3.92 mmol) was added to a stirred suspension of (±)-**37** (1 g, 3.74 mmol) and $NaHCO_3$ (630 mg, 7.5 mmol) in CH_2Cl_2 (20 ml) cooled to 0°. After 30 min stirring at 0°, the solvent was distilled off under vacuum and the residue purified by CC (silica gel (50 g), +15°, AcOEt/light petroleum ether 1:9): 800 mg (48%) of (±)-**38a** (R_f 0.4) and 206 mg (12.5%) of (±)-**38b** (R_f 0.32).

Characteristics of (±)-**38a**: M.p. 120° (dec.). IR (KBr): 3660, 3580, 3000–2860, 2100, 1780, 1730, 1580, 1470, 1425, 1350, 1260, 1120, 1040, 1000, 910, 870, 840. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.04, 7.95, 7.60, 7.42 (4 H, arom. CH); 4.65 (*s*, H–C(2)); 4.47 (br. *s*, ^4J = 1.4, 1.3, H–C(1)); 4.30 (*dd*, ^3J = 5.7, 1.4, H–C(4)); 3.85 (*dd*, ^3J = 7.8, 3.0, H–C(6)); 3.62 (*s*, OH); 2.62 (*dd*, ^2J = 13.5, ^3J = 7.8, H_{endo}–C(5)); 1.75 (*dddd*, ^2J = 13.5, ^3J = 5.7, 3.0, ^4J = 1.4, 1.3, H_{exo}–C(5)); 0.90 (*s*, *t*-Bu); 0.10, 0.05 (2*s*, 2 Me_2Si). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 164.3 (*s*, CO); 134.8, 133.8, 130.5, 129.8, 127.9 (6 arom. C); 102.8 (*s*, C(3)); 86.1, 83.5, 81.2 (3*d*, ^1J(C,H) = 155, 150, 160, C(1), C(2), C(4)); 59.4 (*d*, ^1J(C,H) = 150, C(6)); 31.6 (*t*, ^1J(C,H) = 135, C(5)); 25.7 (*q*, Me_3C); 17.6 (*s*, Me_3C); −1.0 (*q*, 2 Me). CI-MS (NH_3): 382 (4), 226 (3), 215 (2), 213 (3), 142 (3), 141 (25), 140 (5), 139 (73), 132 (4), 129 (3), 95 (3), 93 (5), 92 (7), 84 (5), 77 (6), 75 (100). Anal. calc. for $C_{19}H_{26}ClN_3O_5Si$ (439.97): C 51.86, H 5.96, N 9.55; found: C 51.38, H 5.84, N 9.60.

Characteristics of (±)-**38b**: Colourless crystals. M.p. 116–118° (dec.). IR (KBr): 3950, 3700, 3550, 3000, 2690, 2520, 2400, 2300, 2100, 1735, 1420, 1250, 1110, 1000, 900, 840. ^{1}H-NMR (250 MHz, $CDCl_3$): 7.95, 7.92, 7.55, 7.40 (4 H, arom. CH); 4.70 (*d*, ^3J = 5.5, H–C(1)); 4.40 (br. *s*, ^4J = 1.3, 1.2, H–C(4)); 3.79 (*d*, ^3J = 4.5, H–C(3)); 3.6 (*dd*, ^3J = 7.8, 2.9, H–C(5)); 3.1 (*d*, ^3J = 4.5, OH); 2.33 (*dd*, ^2J = 14.5, ^3J = 7.8, H_{endo}–C(6)); 1.93 (*dddd*, ^2J = 14.5, ^3J = 5.5, 2.9, ^4J = 1.2, H_{exo}–C(6)); 0.84 (*s*, *t*-Bu); 0.12, 0.05 (2*s*, 2 Me). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 163.0 (*s*, CO); 134.6, 133.6, 130.9, 129.8, 129.3, 127.5 (6 arom. C); 105.2 (*s*, C(2)); 87.3, 80.4, 76.7 (3*d*, ^1J(C,H) = 165, 162, 150, C(1), C(3), C(4)); 59.0 (*d*, ^1J(C,H) = 150, C(5)); 31.8 (*t*, ^1J(C,H) = 135, C(6)); 25.2 (*q*, ^1J(C,H) = 125, Me_3C); 17.9 (*s*, Me_3C); −0.7 (*q*, 2 Me). CI-MS (NH_3): 333 (100), 315 (12), 301 (33), 298 (15), 258 (14), 226 (12), 243 (9), 129 (14), 126 (9), 113 (10), 92 (17), 91 (10), 90 (26), 75 (39). Anal. calc. for $C_{19}H_{26}ClN_3O_5Si$ (439.97): C 51.86, H 5.96, N 9.55; found: C 51.56, H 6.00, N 9.65.

*6-*exo*-Azido-3-oxo-7-oxabicyclo[2.2.1]hept-2-*exo*-yl 3-Chlorobenzoate* ((±)-**39**). The crude mixture (±)-**38a**/(±)-**38b** was heated to 120° for 20 min under stirring. After cooling to 0°, the solid was washed with hexane (5 ml) and then dissolved in a minimum amount of CH_2Cl_2. Addition of hexane (crystallization by solvent diffusion) gave 400 mg (81%) of white crystals. M.p. 114–115°. IR (KBr): 3250, 2100, 1780, 1730, 1570, 1430, 1370, 1340, 1290, 1260, 1130, 990, 905, 820, 740. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.00, 7.93, 7.57, 7.40 (4 H, arom. CH); 4.91 (*s*, H–C(2)); 4.82 (br. *s*, ^4J = 1.1, H–C(1)); 4.63 (*d*, ^3J = 6.2, H–C(4)); 4.05 (*dd*, ^3J = 7.7, 3.2, H–C(6)); 2.32 (*dd*, ^2J = 14.5, ^3J = 7.7, H_{endo}–C(5)); 2.15 (*dddd*, ^2J = 14.5, ^3J = 6.2, 3.2, ^4J = 1.1, H_{exo}–C(5)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 164.6 (*s*, C(3)); 134–127 (6 arom. C); 85.1 (*d*, ^1J(C,H) = 168, C(1)); 77.9 (*d*, ^1J(C,H) = 172, C(2)); 71.0 (*d*, ^1J(C,H) = 150, C(4)); 58.9 (*d*, ^1J(C,H) = 150, C(6)); 32.4 (*t*, ^1J(C,H) = 139, C(5)). CI-MS (NH_3): 308 (6, $[M + 1]^+$), 158 (3), 156 (7), 142 (2), 141 (31), 140 (6), 139 (100), 128 (2), 126 (9), 125 (2), 123 (2), 114 (2), 113 (7), 111

(20), 104 (2), 99 (5). Anal. calc. for $C_{13}H_{10}ClN_3O_4$ (307.69): C 50.74, H 3.28, N 13.66; found: C 50.65, H 3.18, N 13.67.

*3-Azido-5-O-(3-chlorobenzoyl)-2,3-dideoxy-β-*DL-ribo-*hexofuranurono-6,1-lactone* ((±)-**40**). The 3-$ClC_6H_4CO_3H$ (85%; 1.14 g, 5.6 mmol) was added portionwise to a soln. of (±)-**37** (1 g, 3.74 mmol) in THF (20 ml) stirred at 25° (TLC, CH_2Cl_2/light petroleum ether 3:1, R_f 0.53 ((±)-**37**), 0.43 ((±)-**38a**)). After 45 min, the solvent was evaporated and the residue heated to 120° for 15 min. After cooling to 25°, $CHCl_3$ (20 ml) was added and the soln. cooled to 0°. $NaHCO_3$ (*1 g, 12 mmol*) and 3-$ClC_6H_4CO_3H$ (*85%; 800 mg, 3.92 mmol*) were added, and the mixture was stirred at 0° for 3 h (TLC, AcOEt/CH_2Cl_2 1:30, R_f 0.6 ((±)-**40**)). The precipitate was filtered off and washed with CH_2Cl_2 (10 ml, 3 times), the combined org. phase washed with 5% aq. $NaHCO_3$ soln. cooled to 0° (ice), dried ($MgSO_4$), and evaporated without heating, and the residue recrystallized from CH_2Cl_2/hexane: 527 mg (43.3%). Unstable, colourless crystals. M.p. 47° (dec.). UV (95% EtOH): 280 (1000), 230 (5000): ε_{210} = 17600. IR ($CHCl_3$): 3040, 2100, 1770, 1735, 1445, 1375, 1235, 1180, 1140, 990. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.08, 8.00, 7.61, 7.45 (4 H, arom. CH); 6.18 (*dd*, ^3J = 4.8, ^4J < 1.0, H–C(1)); 5.45 (*d*, ^3J < 1.0, H–C(5)); 4.76 (*d*, ^3J < 1.0, H–C(4)); 4.31 (*dd*, ^3J = 7.5, 2.8, H–C(3)); 2.80 (*dd*, ^2J = 15.1, ^3J = 7.5, H_{endo}–C(2)); 2.38 (*dddd*, ^2J = 15.1, ^3J = 4.8, 2.8, ^4J < 1, H_{exo}–C(2)). ^{13}C-NMR (*62.9 MHz, $CDCl_3$*): 164.0, 161.0 (2*s*, 2 CO); 134.1, 133.7, 130.2, 130.0, 129.8, 128.3 (6 arom. C); 102.8 (*d*, ^1J(C,H) = 188, C(1)); 84.4 (*d*, ^1J(C,H) = 165, C(5)); 70.6 (*d*, ^1J(C,H) = 145, C(4)); 59.4 (*d*, ^1J(C,H) = 151, C(3)); 40.6 (*t*, ^1J(C,H) = 135, C(2)). EI-MS (70 eV): 324 (2, $[M + 1]^+$), 312 (2), 226 (57), 143 (30), 142 (20), 140 (24), 129 (79), 126 (31), 101 (28), 85 (15), 75 (100), 73 (77), 71 (19), 69 (15), 61 (18), 59 (50), 57 (48), 55 (52), 54 (17). Anal. calc. for $C_{13}H_{10}ClN_3O_5$ (323.56): C 48.21, H 3.10; found: C 48.35, H 3.22.

*(Methyl 3-Azido-5-O-(3-chlorobenzoyl)-2,3-dideoxy-α- and -β-*DL-ribo-*hexofuranosid)uronic Acids* ((±)-**41a** and (±)-**41b**, resp.). MsOH (22 µl, 0.34 mmol) was added to a stirred soln. of (±)-**40** (100 mg, 0.31 mmol) in anh. MeOH (5 ml) cooled to −15° under Ar. After stirring at −15° for 2 h, AcONa (33.5 mg, 0.4 mmol) was added (precipitation of MsONa). The precipitate was filtered off and washed with Et_2O (5 ml, 3 times). The combined org. phase was washed with H_2O (5 ml) and 5% aq. $NaHCO_3$ soln. (3 ml, 5 times). The combined aq. phase was extracted with $CHCl_3$ (5 ml). After acidification of the aq. phase to pH 3 with 2N HCl, it was extracted again with AcOEt (5 ml, 3 times). The combined latter org. extracts were washed with brine (5 ml, twice), dried ($MgSO_4$), and evaporated: 69 mg (63%) of a 9:1 mixture **41a**/**41b**. Recrystallization from $CHCl_3$/pentane yielded 58 mg (51%) of pure **41a**.

Characteristics of (±)-**41a**: Colourless crystals. M.p. 68–69°. UV (EtOH): 280 (6700), 240 (8750); ε_{210} = 17000. IR ($CHCl_3$): 2900, 2100 (N_3), 1760 (CO), 1420, 1240, 1125, 1100, 1050, 965, 900. ^{1}H-NMR (250 MHz, $CDCl_3$): 8.10, 7.95, 7.60, 7.43 (4 H, arom. CH); 5.60 (*d*, ^3J = 2.9, H–C(5)); 5.16 (*dd*, ^3J = 5.1, 1.0, H–C(1)); 4.52 (*dd*, ^3J = 4.9, 2.9, H–C(4)); 4.46 (*ddd*, ^3J = 9.0, 4.9, 2.5, H–C(3)); 3.41 (*s*, MeO); 2.48 (*ddd*, ^2J = 13.5, ^3J = 9.0, 5.1, H–C(2) *trans* to N_3); 2.12 (*ddd*, ^2J = 13.5, ^3J = 2.5, 1.0, H–C(2) *cis* to N_3). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 172.1, 164.5 (2*s*, 2 CO); 140–130 (6 arom. C); 105.0 (*d*, ^1J(C,H) = 171, C(5)); 81.7 (*d*, ^1J(C,H) = 153, C(1)); 72.3 (*d*, ^1J(C,H) = 152, C(4)); 60.0 (*d*, ^1J(C,H) = 152, C(3)); 55.3 (*q*, MeO); 38.9 (*t*, ^1J(C,H) = 133, C(2)). EI-MS (70 eV): 355 (1, $M^{+\cdot}$), 324 (1), 224 (1), 223 (1), 211 (1), 210 (1), 208 (1), 157 (1), 156 (3), 142 (3), 140 (2), 139 (25), 111 (19), 86 (15), 84 (13), 75 (17), 59 (14), 58 (100), 55 (10). Anal. calc. for $C_{14}H_{14}ClN_3O_6$ (355.56): C 47.27, H 3.99; found: C 46.93, H 3.99.

Characteristics of (±)-**41b** (from the mixture with (±)-**41a**): ^{1}H-NMR (250 MHz, $CDCl_3$): 8.10–7.43 (4 H, arom. CH); 5.40 (*d*, ^3J = 4.7, H–C(5)); 5.16 (*d*, ^3J = 4.9, H–C(1)); 4.58 (*dd*, H–C(4)); 4.40 (*ddd*, ^3J = 7.1, 4.7, 2.9, H–C(3)); 3.23 (*s*, MeO); 2.42 (*m*, H–C(2) *trans* to N_3); 2.21 (*m*, H–C(2) *cis* to N_3). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 172.5, 170.7 (2*s*, 2 CO); 140–130 (6 arom. C); 105.0 (*d*, ^1J(C,H) = 171, C(5)); 82.4 (*d*, ^1J(C,H) = 153, C(1)); 72.6 (*d*, ^1J(C,H) = 152, C(4)); 60.3 (*d*, ^1J(C,H) = 152, C(3)); 55.3 (*q*, MeO); 38.8 (*t*, ^1J(C,H) = 133, C(2)).

Mixture of (−)-**22** *and (3S)-3,4-Dihydro-8-hydroxy-3-{(1'S)-3'-methyl-1'-{[(methyl 3''-azido-5''-O-(3-chlorobenzoyl)-2'',3''-dideoxy-α-*L-ribo-*hexofuranosid)uronyl]amino}butyl}-1*H*-2-benzopyran-1-one* (*= {Methyl 3-Azido-5-O-(3-chlorobenzoyl)-2,3-dideoxy-*N*-{(1'S)-1'-[(3''S)-3'',4''-dihydro-8''-hydroxy-1''-oxo-1''*H*-2''-benzopyran-3''-yl]-3'-methylbutyl}-α-*L-ribo-*hexofuranosid}uronamide*; (−)-**42**). Obtained by the procedure described above for the preparation of (−)-**20**, starting with (−)-**2** (111 mg, 0.38 mmol) and (±)-**41a**/(±)-**41b** (136 mg, 0.38 mmol). CC (silica gel (10 g), AcOEt/light petroleum ether 1:6) gave 187.3 mg (84.3%) of a non-separable 1:1 mixture (−)-**22**/(−)-**42**.

Pure (−)-**42** was also prepared following the procedure described above for the preparation of (−)-**22**, starting with (−)-**21** (50 mg) and NaN_3 (78 mg): 37 mg (39%) of (−)-**42**. Colourless oil. $[\alpha]_{589}^{25} = -34$, $[\alpha]_{578}^{25} = -46$, $[\alpha]_{546}^{25} = -46$, $[\alpha]_{436}^{25} = -73$, $[\alpha]_{365}^{25} = -158$ (*c* = 0.48, CH_2Cl_2). IR ($CHCl_3$): 3420, 2950, 2100, 1760, 1680, 1580, 1460, 1230, 1110, 1045, 800. ^{1}H-NMR (250 MHz, $CDCl_3$): 10.76 (*s*, OH); 7.92, 7.81, 7.58, 7.39 (4 H, arom. CH); 7.39 (*dd*, ^3J = 8.5, 7.5, H–C(6)); 6.83, 6.68 (2*d*, ^3J = 8.5, 7.5, H–C(5), H–C(7)); 6.20 (*d*, ^3J = 10.0, NH); 5.35 (*d*, ^3J = 4.1, H–C(5'')); 5.01 (*dd*, ^3J = 5.2, 1.2, H–C(1'')); 4.58 (*ddd*, ^3J = 13.5, 3.1, 1.3, H–C(3)); 4.39 (*ddd*, ^3J = 10.5,

4.5, 1.3, H–C(1′)); 4.37 (*dd*, ^3J = 4.1, 4.8, H–C(4″)); 4.25 (*ddd*, ^3J = 8.9, 4.8, 2.9, H–C(3″)); 3.27 (*s*, MeO); 3.09 (*dd*, ^2J = 16.5, ^3J = 13.5, H_{trans}–C(4)[3])); 2.78 (*dd*, ^2J = 16.5, ^3J = 3.1, H_{cis}–C(4)[3])); 2.38 (*ddd*, ^2J = 14.2, ^3J = 8.9, 5.2, H_{trans}–C(2)[5])); 2.07 (*ddd*, ^2J = 14.2, ^3J = 2.9, 1.2, H_{cis}–C(2″)[5])); 1.88 (*ddd*, ^2J = 15.5, ^3J = 10.5, 4.6, H–C(2′)); 1.62 (*ddq*, ^3J = 12.7, 6.5, 4.6, H–C(3′)); 1.40 (*ddd*, ^2J = 15.5, ^3J = 12.7, 4.5, H–C(2′)); 0.95 (2*d*, ^3J = 6.5, 2 Me–C(3)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 169.1 (*s*, arom. C); 166.9, 164.4 (2*s*, 2 CO); 162.1 (*s*, C(8)); 139.3 (*s*, C(4a)); 136.6 (*d*, ^1J(C,H) = 162, C(6)); 134.9, 133.0, 130.0 (3*d*, ^1J(C,H) = 160, arom. CH); 129.9 (*s*, arom. C); 118.3, 116.2 (2*d*, ^1J(C,H) = 160, C(5), C(7)); 107.6 (*s*, C(8a)); 105.1 (*d*, ^1J(C,H) = 168, C(1″)); 81.9 (*d*, ^1J(C,H) = 154, C(3)); 81.1 (*d*, ^1J(C,H) = 154, C(5″)); 74.8 (*d*, ^1J(C,H) = 152, C(4″)); 60.7 (*d*, ^1J(C,H) = 152, C(3″)); 55.2 (*q*, ^1J(C,H) = 141, MeO); 49.1 (*d*, ^1J(C,H) = 140, C(1′)); 40.7 (*t*, ^1J(C,H) = 130, C(4)); 38.6 (*t*, ^1J(C,H) = 140, C(2″)); 30.1 (*t*, ^1J(C,H) = 132, C(2′)); 24.6 (*d*, ^1J(C,H) = 130, C(3′)); 23.1, 21.7 (2*q*, ^1J(C,H) = 125, 2 Me–C(3′)). CI-MS (NH_3): 417 (6), 374 (20), 373 (28), 356 (29), 307 (14), 246 (14), 231 (9), 215 (12), 211 (23), 210 (15), 195 (13), 173 (16), 135 (29), 86 (100).

Mixture of (–)-**28** *and (3*S*)-3-{(1′*S*)-1′-{[(3″-Azido-5″-*O*-(3-chlorobenzoyl)-2″,3″-dideoxy-α-*L*-ribo-hexaro-1″,4″-lactone)-6″-oyl]amino}-3′-methylbutyl}-3,4-dihydro-8-hydroxy-1*H*-2-benzopyran-1-one* (= {*4-Azido-2-*O*-(3-chlorobenzoyl)-4,5-dideoxy-*N*-{(1′*S*)-1′-[(3″*S*)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl}-α-*L*-ribo-hexaro-6,3-lactone}-1-amic Acid*; (–)-**43**)[6]). The 3-$ClC_6H_4CO_3H$ (35%; 16 mg, 0.075 mmol) was added to a stirred soln. of a 1:1 mixture (–)-**22**/(–)-**42** (40 mg, 0.068 mmol) in anh. CH_2Cl_2 (0.15 ml). $BF_3 \cdot Et_2O$ (3 drops) was then added and the mixture stirred at 20° for 4 h. Evaporation and CC (silica gel (5 g), AcOEt/light petroleum ether) gave first 16.9 mg (43.5%) of (–)-**28** (see above) and then 20 mg (51.5%) of (–)-**43**.

(–)-**43**: Colourless crystals. M.p. 92°. $[\alpha]_{589}^{25} = -42$, $[\alpha]_{578}^{25} = -47$, $[\alpha]_{546}^{25} = -58$, $[\alpha]_{436}^{25} = -135$, $[\alpha]_{365}^{25} = -309$ (*c* = 0.17, MeOH). IR (KBr): 2960, 2430 (OH), 2100 (N_3), 1790, 1730, 1670, 1620 (CO), 1530, 1460, 1285, 1245, 1160, 1110, 1045. ^{1}H-NMR (250 MHz, $CDCl_3$): 10.66 (*s*, OH); 7.92, 7.85, 7.62, 7.45 (4 H, arom. CH); 7.47 (*dd*, ^3J = 8.5, 7.6, H–C(6)); 6.91 (*d*, ^3J = 8.5, H–C(5)); 6.73 (*d*, ^3J = 7.6, H–C(7)); 6.38 (*d*, ^3J = 9.5, NH); 5.60 (*d*, ^3J = 2.4, H–C(5″)); 4.90 (*ddd*, ^3J = 8.5, 4.8, 4.6, H–C(3″)); 4.72 (*dd*, ^3J = 4.6, 2.4, H–C(4″)); 4.58 (*ddd*, ^3J = 13.0, 3.1, 1.3, H–C(3)); 4.37 (*ddd*, ^3J = 10.5, 4.7, 1.3, H–C(1′)); 3.09 (*dd*, ^2J = 18.0, ^3J = 8.5, H_{trans}–C(2″)[4])); 3.01 (*dd*, ^2J = 16.3, ^3J = 13.0, H_{trans}–C(4)[3])); 2.80 (*dd*, ^2J = 16.3, ^3J = 3.1, H_{cis}–C(4)[3])); 2.64 (*dd*, ^2J = 18.0, ^3J = 4.8, H_{cis}–C(2″)[4])); 1.85 (*ddd*, ^2J = 13.5, ^3J = 10.5, 4.7, H–C(2′)); 1.41 (*ddd*, ^3J = 9.0, 6.6, 4.7, H–C(3′)); 1.24 (*ddd*, ^2J = 13.5, ^3J = 9.0, 4.7, H–C(2′)); 0.93 (2*d*, ^3J = 6.5, 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 172.7 (*s*, C(1″)); 168.9 (*s*, C(1)); 165.7, 164.1 (2*s*, 2 CO); 162.1 (*s*, C(8)); 138.9 (*s*, C(4a)); 136.6 (*d*, arom. CH); 135.1 (*s*, arom. C); 134.5 (*d*, ^1J(C,H) = 162, C(6)); 130.3, 129.9, 127.8 (3*d*, arom. CH); 129.6 (*s*, arom. C); 118.2, 116.3 (2*d*, ^1J(C,H) = 164, 165, (C(5), C(7)); 108.0 (*s*, C(8a)); 82.8 (*d*, ^1J(C,H) = 165, C(3)); 80.7 (*d*, ^1J(C,H) = 147, C(5″)); 74.0 (*d*, ^1J(C,H) = 149, C(4″)); 57.4 (*d*, ^1J(C,H) = 153, C(3″)); 49.4 (*d*, ^1J(C,H) = 136, C(1′)); 40.4 (*t*, ^1J(C,H) = 125, C(4)); 34.6 (*t*, ^1J(C,H) = 135, C(2″)); 30.2 (*t*, ^1J(C,H) = 132, C(2′)); 24.6 (*d*, ^1J(C,H) = 127, C(3′)); 23.0, 21.5 (2*q*, ^1J(C,H) = 123, 2 Me–C(3′)). EI-MS (70 eV): 591 (22), 590 (38), 589 (56, $[M + 18]^+$), 586 (47), 575 (13), 574 (36), 573 (57), 572 (89 $[M + 1]^+$), 571 (72, M^+), 553 (9), 545 (10), 544 (12), 543 (9), 322 (7), 252 (25), 232 (12), 231 (23), 230 (25), 225 (14), 224 (14), 215 (10), 210 (11), 198 (39), 197 (44), 175 (15), 163 (16), 156 (17), 141 (31), 139 (100), 111 (19), 93 (18), 86 (51), 77 (19).

*(3*S*)-3-{(1′*S*)-1′-{[(3″-Amino-5″-*O*-(3-chlorobenzoyl)-2″,3″-dideoxy-α-*L*-ribo-hexaro-1″,4″-lactone)-6″-oyl]-amino}-3′-methylbutyl}-3,4-dihydro-8-hydroxy-1*H*-2-benzopyrano-1-one* (= {*4-Amino-2-*O*-(3-chlorobenzoyl)-4,5-dideoxy-*N*-{(1′*S*)-1′-[(3″*S*)-3″,4″-dihydro-8″-hydroxy-1″-oxo-1″*H*-2″-benzopyran-3″-yl]-3′-methylbutyl}-α-*L*-ribo-hexaro-6,3-lactone}-1-amic Acid*; (–)-**44**)[6]). Prepared as described above for (–)-**29**, starting with (–)-**43**. Yield 89%, colourless crystals. M.p. 94–95°. $[\alpha]_{589}^{25} = -10$, $[\alpha]_{578}^{25} = -18$, $[\alpha]_{546}^{25} = +20$, $[\alpha]_{436}^{25} = +122$, $[\alpha]_{365}^{25} = +123$, (*c* = 0.15, MeOH): IR (KBr): 3400, 2980, 1790, 1730, 1680, 1620, 1535, 1460, 1230, 1210, 1110, 810. ^{1}H-NMR (250 MHz, $CDCl_3$): 7.87, 7.80, 7.57, 7.40 (4 H, arom. CH); 7.39 (*dd*, ^3J = 8.5, 7.5, H–C(6)); 6.85 (*d*, ^3J = 7.5, H–C(7)); 6.60 (*d*, ^3J = 8.5, H–C(5)); 5.60 (*d*, ^3J = 2.6, H–C(5″)); 4.62 (*dd*, ^3J = 5.5, 2.6, H–C(4″)); 4.55 (*ddd*, ^3J = 13.0, 2.9, 2.1, H–C(3)); 4.37 (*ddd*, ^3J = 10.6, 4.9, 2.1, H–C(1′)); 4.22 (*ddd*, ^3J = 8.2, 6.8, 5.5, H–C(3″)); 3.05 (*dd*, ^2J = 16.5, 13.0, H_{trans}–C(4)[3])); 2.97 (*dd*, ^2J = 17.9, ^3J = 8.2, H_{trans}–C(2″)[5])); 2.80 (*dd*, ^2J = 16.5, ^3J = 2.9, H_{cis}–C(4)[3])); 2.40 (*dd*, ^2J = 17.9, ^3J = 6.8, H_{cis}–C(2″)[5])); 1.92 (*ddd*, ^2J = 13.9, ^3J = 10.6, 4.8, H–C(2′)); 1.68 (*ddd*, ^3J = 9.3, 6.5, 4.8, H–C(3′)); 1.49 (*ddd*, ^2J = 13.9, ^3J = 9.3, 4.9, H–C(2′)); 0.93 (2*d*, ^3J = 6.5 2 Me–C(3′)). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 173.9 (*s*, C(1″)); 169.1 (*s*, C(1)); 166.1, 164.3 (2*s*, 2 CO); 162.0 (*s*, C(8)); 139.0 (*s*, (4a)); 136.5 (*d*, arom. CH); 135.0 (*s*, arom. C); 134.2 (*d*, ^1J(C,H) = 160, C(6)); 130.1, 129.7, 129.7 (3*d*, arom. CH); 127.8 (*s*, arom. C); 118.2, 116.2 (2*d*, ^1J(C,H) = 165, 163, C(5), C(7)); 107.6 (*s*, C(8a)); 85.6 (*d*, ^1J(C,H) = 155, C(3)); 80.9 (*d*, ^1J(C,H) = 156, C(5″)); 74.1 (*d*, ^1J(C,H) = 152, C(4″)); 49.3 (*d*, ^1J(C,H) = 143, C(3″)); 49.1 (*d*, ^1J(C,H) = 138, C(1′)); 40.1 (*t*, ^1J(C,H) = 127, C(4)); 37.8 (*t*, ^1J(CH) = 136, C(2″)); 30.1 (*t*, ^1J(C,H) = 132, C(2′)); 24.5 (*d*, ^1J(C,H) = 123, C(3′)); 23.0, 21.4 (2*q*, ^1J(C,H) = 124, 2 Me–C(3′)). CI-MS (NH_3): 546 (3, $[M + 1]^+$), 545 (9, M^+), 383 (5), 382 (32), 366

(12), 339 (37), 270 (9), 258 (8), 248 (15), 232 (9), 230 (12), 215 (10), 201 (12), 178 (8), 175 (9), 157 (30), 156 (37), 155 (82), 141 (47), 139 (100), 135 (23), 111 (43), 101 (22), 96 (20), 93 (24), 86 (90), 77 (43).

*(3S)-3-{(1'S)-1'-[(3"-Amino-2",3"-dideoxy-α-L-*ribo*-hexar-6"-oyl)amino]-3'-methylbutyl}-3,4-dihydro-8-hydroxy}-1H-benzopyran-1-one* (= *{4-Amino-4,5-dideoxy-N-{(1'S)-1'-[(3"S)-3",4"-dihydro-8"-hydroxy-1"-oxo-1"H-2"-benzopyran-3"-yl]-3'-methylbutyl}-α-L-*ribo*-hexar-1-amic Acid*; (–)-**45**). Prepared as described above for (–)-**1**, starting with (–)-**44**. Yield 60%, colourless oil. $[\alpha]_{589}^{25} = -11$, $[\alpha]_{578}^{25} = -7$, $[\alpha]_{546}^{25} = +1$, $[\alpha]_{436}^{25} = +15$, $[\alpha]_{365}^{25} = +10$ ($c = 0.48$, MeOH). IR (THF): 3570, 3500, 2800, 1800, 1680, 1630, 1590, 1520, 1000. ^{1}H-NMR (250 MHz, CD_3CN): 7.43 (*dd*, $^3J = 8.4$, 8.1, H–C(6)); 7.2 (*d*, $^3J = 10.0$, NH); 6.82, 6.79 (2*d*, $^3J = 8.4$, 8.1, H–C(5), H–C(7)); 4.95 (*dd*, $^3J = 2.7$, 2.3, H–C(4")); 4.63 (*ddd*, $^3J = 8.3$, 7.9, 4.3, H–C(3)); 4.50 (*d*, $^3J = 2.3$, H–C(5")); 4.30 (*ddd*, $^3J = 9.0$, 2.8, 2.7, H–C(3")); 4.21 (*m* H–C(1')); 3.10 (*dd*, $^2J = 16.6$, $^3J = 4.3$, H_{cis}–C(4)^3)); 3.04 (*dd*, $^2J = 18.5$, $^3J = 9.0$, H–C(2")); 3.03 (*dd*, $^2J = 16.6$, $^3J = 8.5$, H_{trans}–C(4)^3)); 2.72 (*dd*, $^2J = 18.5$, $^3J = 2.8$, H–C(2")); 1.70 (*m*, H–C(3'), H–C(2')); 1.40 (*ddd*, $^2J = 14.4$, $^3J = 11.0$, 4.5, H–C(2')); 0.93 (2*d*, $^3J = 6.3$, 2 Me–C(3')). ^{13}C-NMR (62.9 MHz, $CDCl_3$): 72.8 (*s*, C(1")); 170.2 (*s*, C(1)); 170.4 (*s*, C(8)); 161.7 (*s*, C(6")); 139.9 (*s*, C(4a)); 137.2 (*d*, ^1J(C,H) = 160, C(6)); 119.1, 116.0 (2*d*, ^1J(C,H) = 155, 160, C(5), C(7)); 108.5 (*s*, C(8a)); 82.0 (*d*, ^1J(C,H) = 155, C(3)); 81.0 (*d*, ^1J(C,H) = 152, C(5")); 71.1 (*d*, ^1J(C,H) = 148, C(4")); 48.7 (*d*, ^1J(C,H) = 139, C(3")); 48.6 (*d*, ^1J(C,H) = 155, C(1')); 38.8 (*t*, ^1J(C,H) = 125, C(4)); 32.9 (*t*, ^1J(C,H) = 137, C(2")); 29.3 (*t*, ^1J(C,H) = 130, C(2')); 24.2 (*d*, ^1J(C,H) = 135, C(3')); 21.3, 19.4 (2*q*, 2 Me–C(3')). CI-MS (NH_3): 451 (15), 439 (11), 433 (2), 419 (8), 320 (20), 306 (11), 262 (6), 244 (21), 230 (13), 201 (21), 144 (13), 135 (47), 122 (13), 114 (12), 107 (15), 86 (100).

REFERENCES

[1] P. Péchy, F. Gasparini, P. Vogel, *Synlett* **1992,** 676.

[2] Y. Shimojima, H. Hayashi, T. Ooka, M. Shibukawa, *Agric. Biol. Chem.* **1982,** *46,* 1823.

[3] Y. Shimojima, H. Hayashi, *J. Med. Chem.* **1983,** *26,* 1370.

[4] a) Y. Shimojima, H. Hayashi, T. Ooka, M. Shibukawa, Y. Iitaka, *Tetrahedron Lett.* **1982,** *23,* 5435; b) Y. Shimojima, H. Hayashi, T. Ooka, M. Shibukawa, Y. Iitaka, *Tetrahedron* **1984,** *40,* 2519.

[5] Y. Hamada, A. Kawa, Y. Kohno, O. Hara, T. Shiori, *J. Am. Chem. Soc.* **1989,** *111,* 1524; Y. Hamada, O. Hara, A. Kawai, Y. Kohno, T. Shioiri, *Tetrahedron* **1991** *47,* 8635; see also: A. Kawai, O. Hara, Y. Hamada, T. Shioiri, *Tetrahedorn Lett.* **1988,** *29,* 6331.

[6] S.D. Broady, J.E. Rexhausen, E.J. Thomas, *J. Chem. Soc., Chem. Commun.* **1991,** 708.

[7] J.P. Gesson, J.C. Jacquesy, M. Mondon, *Tetrahedron Lett.* **1989,** *30,* 6503.

[8] R.A. Ward, G. Procter, *Tetrahedron Lett.* **1992,** *33,* 3359.

[9] P. Vogel, Y. Auberson, M.R. Bimwala, E. De Guchteneere, E. Vieira, J. Wagner, in 'Trends in Synthetic Carbohydrate Chemistry', Eds. D. Horton, L.D. Hawkins, and G.J. McGarvey, ACS Symposium Series 386, American Chemical Society, Washington, D.C., 1989, p. 197–241; P. Vogel, *Bull. Soc. Chim. Belg.* **1990,** *99,* 395; P. Vogel, D. Fattori, F. Gasparini, C. Le Drian, *Synlett* **1990,** 173.

[10] A. Warm, P. Vogel, *Tetrahedron Lett.* **1985,** *26,* 5027; A. Warm, P. Vogel, *J. Org. Chem.* **1986,** *51,* 5348.

[11] P. Brownbridge, *Synthesis* **1983,** 1; H.O. House, L.J. Czuba, M. Gall, H.D. Olmstead, *J. Org. Chem.* **1964,** *34,* 2324; T.P. Mawhinney, M.A. Madson, *J. Org. Chem.* **1982,** *47,* 3336.

[12] A.G. Brook, D.M. Macrae, *J. Organomet. Chem.* **1974,** *77,* C19; G.M. Rubottom, M.A. Vasquez, D.R. Pelegrina, *Tetrahedron Lett.* **1974,** 4319; A. Hassner, R.H. Reuss, H.W. Pinnick, *J. Org. Chem.* **1975,** *40,* 3427; J.H. Dodd, J.E. Startett, S.M. Weinreb, *J. Am. Chem. Soc.* **1984,** *106,* 1811; F.A. Davis, A.C. Sheppard, *J. Org. Chem.* **1987,** *52,* 954; L.A. Paquette, H.S. Kin, J.C. Gallucci, *Tetrahedron Lett.* **1987,** *28,* 1363.

[13] H. House, in 'Modern Synthetic Reaction', 2nd edn., W.A. Benjamin, M. Park, California, 1972, p. 314; C.L. Stevens, S.J. Dykstra, *J. Am. Chem. Soc.* **1953,** *75,* 597; E. Colvin, 'Silicon in Organic Chemistry', Butterworth, 1981, p. 236.

[14] Y. Auberson, P. Vogel, *Helv. Chim. Acta* **1989,** *72,* 278; Y. Auberson, P. Vogel, *Tetrahedron* **1990,** *46,* 7019.

[15] R.L. Colbran, T.P. Nevell, *J. Chem. Soc.* **1957,** 2427; K. Heyns, H. Paulsen, G. Rüdiger, J. Weyer, *Fortschr. Chem. Forsch.* **1969,** *11,* 285; K. Heyns, E. Alpers, J. Weyer, *Chem. Ber.* **1968,** *101,* 4209; Y. Rabinsohn, H.G. Fletcher, *J. Org. Chem.* **1967,** *32,* 3452; K. Onodera, S. Hirano, N. Kashimura, *Carbohydr. Res.* **1968,** 267; H. Weidmann, *Monatsh. Chem.* **1965,** *96,* 766; H. Weidmann, G. Olbrich, *Tetrahedron Lett.* **1965,** 725; D.W. Mackie, A.S. Perlin, *Can. J. Chem.* **1965,** *43,* 2921; K. Dax, H. Weidmann, *Carbohydr. Res.* **1972,** *25,* 363; S. Takano, K. Inomato, A. Kurotaki, T. Ohkawa, K. Ogasawara, *J. Chem. Soc., Chem. Commun.* **1987,**

1720; V. Balogh, M. Fétizon, M. Golfier, *J. Org. Chem.* **1971,** *36,* 1339; C.S. Hudson, H.S. Isbell, *J. Am. Chem. Soc.* **1929,** *51,* 2225; O. Han, H.-W. Liu, *Tetrahedron Lett.* **1987,** *28,* 1073; S. Hanessian, D. Hin-Chor Wong, M. Theren, *Synthesis* **1981,** 394.

[16] P.-A. Grieco, T. Ogari, Y. Yokoyama, *Tetrahedron Lett.* **1978,** 419; see also: W.H. Bailey, M.-J. Sih, *J. Am. Chem. Soc.* **1982,** *104,* 1769; *ibid.* **1987,** *109,* 7535.

[17] M. Vaultier, N. Knouzi, R. Carrié, *Tetrahedron Lett.* **1983,** *24,* 763.

[18] M.C. Samano, M.J. Robins, *Tetrahedron Lett.* **1991,** *32,* 6293; see also M. Frankel, D. Wagner, D. Gertner, A. Zilkha, *J. Organomet. Chem.* **1967,** *7,* 518; H. Redlich, W. Roy, *Liebigs Ann. Chem.* **1988,** 1215; N. Maiti, M.P. Singh, R.G. Micetich, *Tetrahedron Lett.* **1986,** *27,* 1423; M. Battra, F. Urpi, J. Vilarosa, *ibid.* **1987,** *28,* 5941.

[19] K.A. Black, P. Vogel, *J. Org. Chem.* **1986,** *51,* 5341.

[20] J.W. Harmersma, E.I. Snyder, *J. Org. Chem.* **1965,** *33,* 3985; W.C. Baird, B. Franzus, J.H. Surridge, *J. Am. Chem. Soc.* **1967,** *89,* 410; W. Adam, H. Eggelte, *Angew. Chem. Int. Ed.* **1978,** *17,* 765.

[21] G. Arvai, D. Fattori, P. Vogel, *Tetrahedron* **1992,** *48,* 10621.

[22] J.-L. Reymond, P. Vogel, *Tetrahedron Asymmetry* **1990,** *1,* 729.

[23] J. Wagner, E. Vieira, P. Vogel, *Helv. Chim. Acta* **1988,** *71,* 624.