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Tandem Radical Mediated 5-exo-trig, 6-endo-dig Cyclization. Stereoselectivity, α-Trimethylsilyl Effect and the Product Spread – IV.

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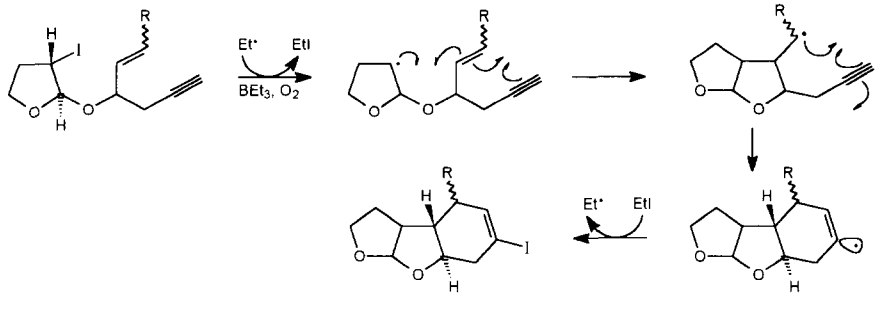
Abstract: Stereochemistry and mechanism of the title reaction have been investigated. The reaction proceeds well in the (*S*) series. In the epimeric (*R*) series a product spread is usually observed. In either series olefin configuration is lost (7 examples), consistent with a freely rotating exocyclic radical intermediate. An α-trimethylsilyl group at the olefinic terminus enhances the selectivity of the radical cascade. Spectroscopic evidence and MMX calculations suggest that the tandem annulation products of the (*S*) series are favoured thermodynamically, being more stable than those of the (*R*) series. Pyranoside (*R*)**G2a** is frozen in a half chair conformation. © 1997 Elsevier Science Ltd.

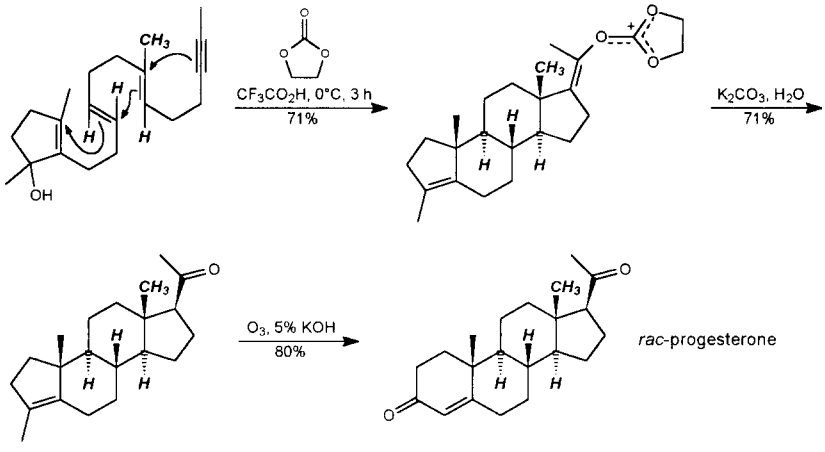
Introduction. We have recently developed a novel radical cascade, which permits the construction of a five-membered ring, which is *trans*-fused to a six-membered ring. Thanks to acetylene termination, the six-membered ring is an iodocyclohexene, which arises in an unusual, 6-endo-dig cyclization (Scheme 1). The sequence has been applied to the synthesis of a variety of annulated glycosides.[1]

Scheme 1.



Our tandem reaction can be contrasted with the final stages of the well known *cationic* polyolefin cascade[2] (Scheme 2). This biomimetic cyclization which is modelled on the Stork-Eschenmoser hypothesis also allows construction of a five-membered ring, which is *trans*-fused to a six-membered, *saturated* ring. Again, an acetylene unit functions as terminator, albeit in a 5-exo-dig manner.[3]

Scheme 2.



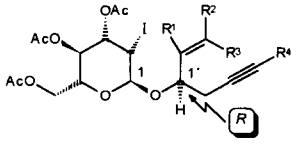
We here describe work, which furnishes insight into mechanism and product type of the title reaction.

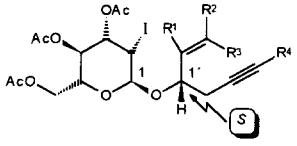
Preparation of Cyclization Precursors and Assignment of Stereochemistry. The cyclization precursors were prepared by an iodoalkoxylation of an electron-rich, cyclic enol ether with *N*-iodosuccinimide (NIS) and a 1-vinylated homopropargyl alcohol.[1] Iodoalkoxylation of 2,3-dihydrofuran is *trans*-selective and furnishes two diastereomers which we have been able to separate. Since the propargyl alcohol is racemic, one obtains racemic cyclization precursors. The diastereomeric 2β-iodo-glucopyranosides are also separable. They are therefore isolated not only diastereopure, but also enantiopure.

We define the carbohydrate cyclization precursors according to the chirality of the 1-vinylated homopropargyl alcohol component and the given anomeric centre, as either (*S*)**G1** or (*R*)**G1** (Scheme 3, **G** = glucal). In order to compare the enantiopure glucal adducts with the model *racemic* dihydrofuran adducts we show only one dihydrofuran enantiomer. All three chiral centres of this enantiomer reappear with the same absolute configuration in the carbohydrate-derived cyclization precursor.

The important stereogenic centre at C(1′) (either *R* or *S*) was recognized and classified by ^{13}C NMR spectroscopy (Table 1). The signal of the proximate, anomeric carbon C(1) was diagnostic: For the (*R*) series the anomeric ^{13}C signal was 3 ppm at higher field (ca.98 ppm) than for the (*S*) series (ca. 101 ppm). The acetalic carbon of the racemic dihydrofuran cyclization precursors showed a similar trend: for the (*R*) series at ca 107 ppm, and for the (*S*) series at ca. 109 ppm (Table 2).[4]

Table 1. Correlation of ^{13}C Shift of Anomeric Carbon C(1) with Absolute Stereochemistry at Carbon C(1′).[a]

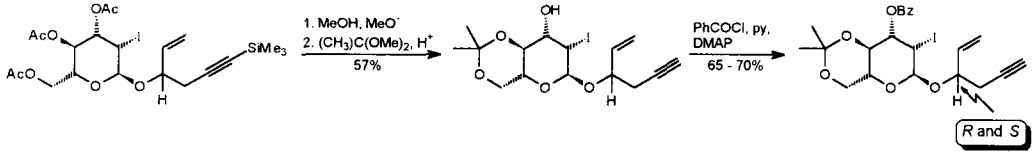




R^1	R^2	R^3	R^4	^{13}C NMR at anomeric C-1	^{13}C NMR at anomeric C-1
H	H	H	H	98.17	101.00
H	H	H	$SiMe_3$	97.71	101.15
H	Me	H	H	97.68	100.94
H	Me	Me	H	97.31	n.a.
H	Me	Me	$SiMe_3$	97.71	102.70
Me	Me	H	H	97.34	101.22
Me	Me	Me	H	97.31	101.44
H	D	H	H	97.21	100.98
H	H	H	H	97.47[b] [(*R*)**G2**]	102.36[b] [(*S*)**G2**]

[a]The absolute configuration of compound (*R*)**G1** was confirmed by combination of glucal with the (*R*) enantiomer of 1-trimethylsilyl-hex-5-en-1-yn-4-ol, obtained by kinetic resolution according to Sharpless.[6]

[b]The carbon-iodine bond stays intact under the chosen experimental conditions.



(*R*)**G2** and (*S*)**G2**

The cyclization of dihydrofuran adduct (*S*)**1** to (*S*)**1a** and that of the epimeric (*R*)**1** to (*R*)**1a** and (*R*)**1b** has been reported[5] (Scheme 3). A simple application in the carbohydrate field is the cyclization of (*S*)**G1** to (*S*)**G1a** and that of epimeric (*R*)**G1** to (*R*)**G1a** and (*R*)**G1b**. We have found that the dihydrofuran and the pyranoside systems show a similar response to conformational and configurational changes in the cyclization precursor.

A priori, the tandem cyclization in the (*R*) series can be formulated as outlined in Scheme 4. The first, 5-exo-trig step (***i*** → ***ii***) is diastereoselective and involves not only a boat-like transition state, but also the axially oriented propynyl group![7] The resulting secondary radical ***ii*** is present in the preferred conformation ***iia***,[8] which, however, does not allow further cyclization. In conformer ***iia*** the reacting termini are disposed *trans*-diaxially and remote from each other. A conformational flip populates the energetically unfavourable gauche arrangement (***iia*** → ***iib***), which is locked by a powerful 6-endo-dig cyclization to cyclic vinyl radical ***iii*** and then by irreversible iodine atom transfer, giving (*R,E*)**3a** and (*R,E*)**3b**.

Scheme 3. Model Study for a 5-exo-trig, 6-endo-dig Cascade. Comparison with a Carbohydrate Annulation. (The dihydrofuran adducts are diastereopure, but racemic).

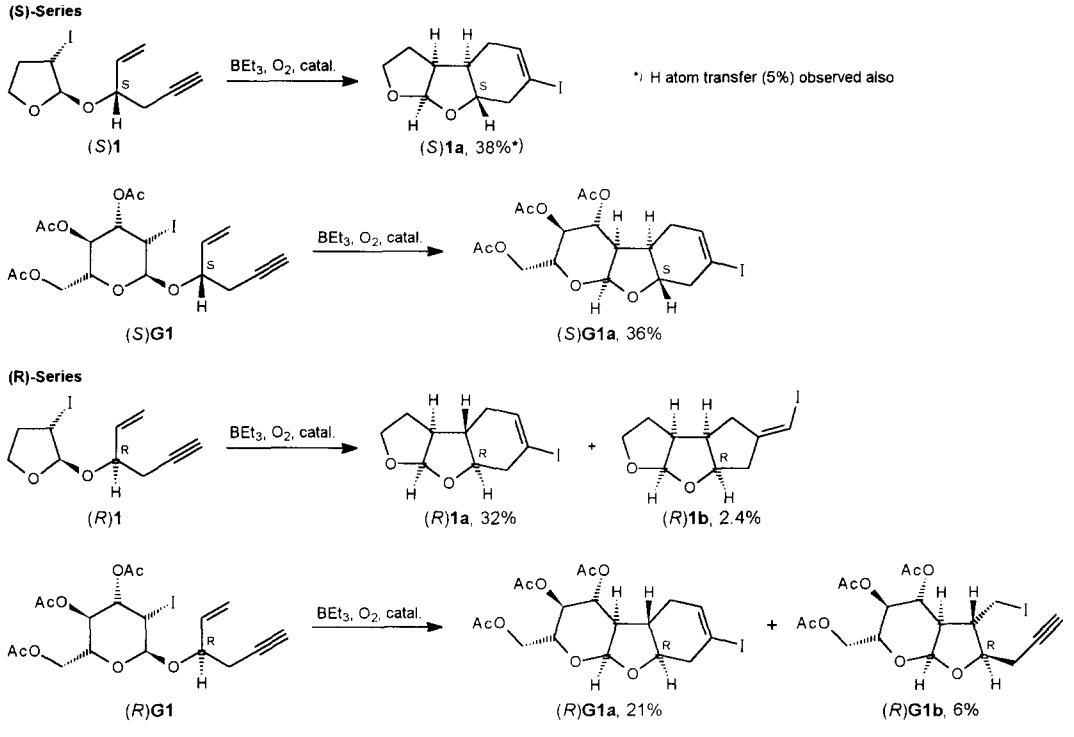
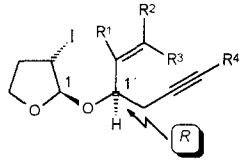
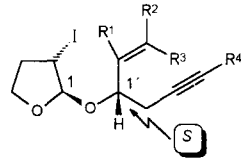


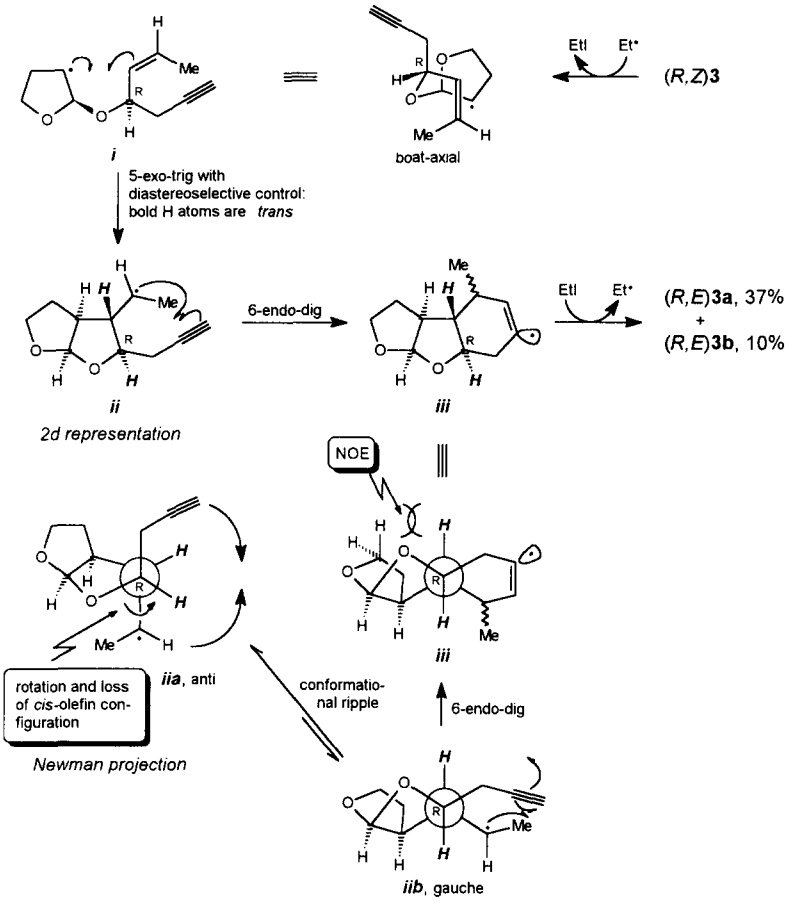
Table 2. Correlation of ^{13}C NMR Shift at C(1) with Relative Stereochemistry at Carbon C(1′).





R^1	R^2	R^3	R^4	^{13}C NMR at C-1	^{13}C NMR at C-1
H	H	H	H	107.54	109.52
H	Me	H	H	107.00	109.12
H	Me	H	$SiMe_3$	106.70	109.25
H	Me	Me	H	106.93	108.67
Me	H	H	H	107.14	109.78
Me	Me	H	H	106.76	109.49
Me	Me	Me	H	106.76	109.55
H	Ph	H	H	107.22	n.a.
H	D	H	H	107.34	109.48
H	H	Me	H	107.09	109.09

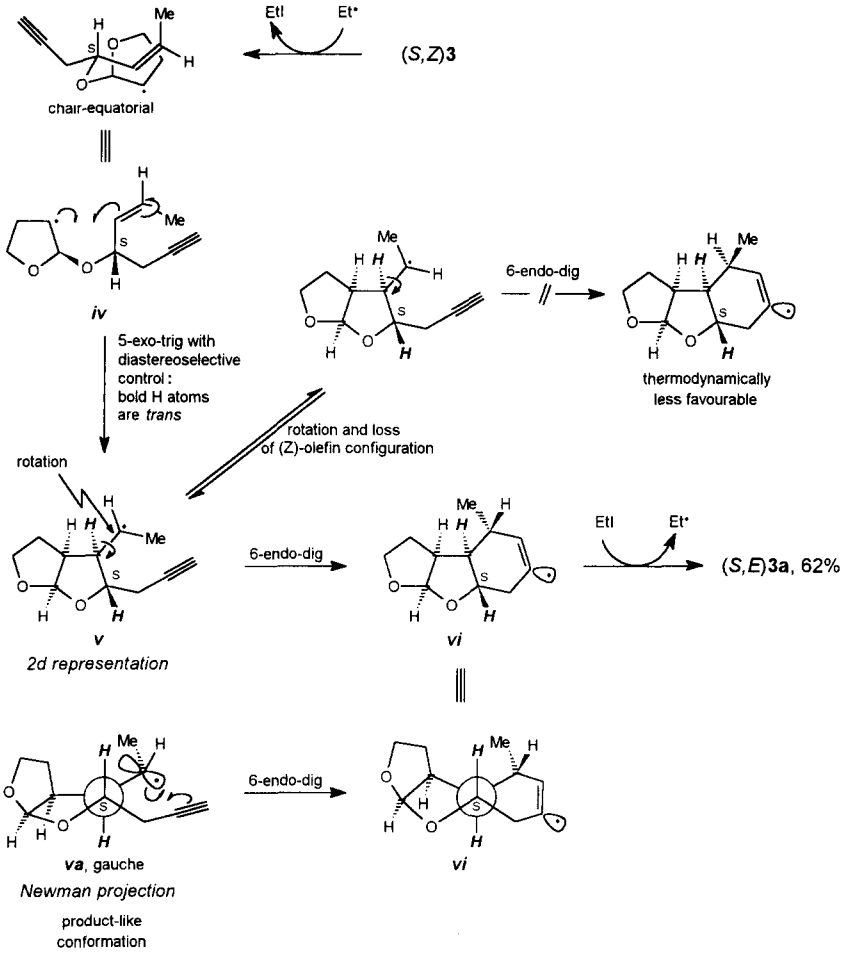
Scheme 4. Configuration and Conformation in the (*R*) Series. Loss of Olefin Configuration, Exemplified for Cyclization of *cis*-Olefinic Substrate (*R,Z*)**3**.



Note that olefin configuration in starting material (*R,Z*)**3** is *lost* in product (*R,E*)**3a** (37%); in (*R,Z*)**3** the olefinic hydrogen atoms are *cis*. In tricycle (*R,E*)**3a** the resulting, tetrahedrally bonded hydrogens are *trans*. In minor tricycle (*R,E*)**3b** (10%) the olefin configuration is retained (Table 3) (see discussion below).

We found that the tandem 5-exo-trig, 6-endo-dig cyclization proceeds more satisfactorily in the (*S*) series (Scheme 5). In contrast to the epimeric (*R*) series the 5-exo-trig cyclization proceeds by a conventional Beckwith-Houk[9] chair-equatorial transition state and furnishes the product-like radical *v*, in which the reacting termini are arranged gauche (while the two hydrogen atoms are now *trans*-diaxial) (cf. ***va***). This conformation is expected to facilitate the radical cascade in the (*S*) series.

Scheme 5. Configuration and Conformation in the (*S*)-Series. Loss of Olefin Configuration, Exemplified for Cyclization of *cis*-Olefinic Substrate (*S,Z*)**3**.

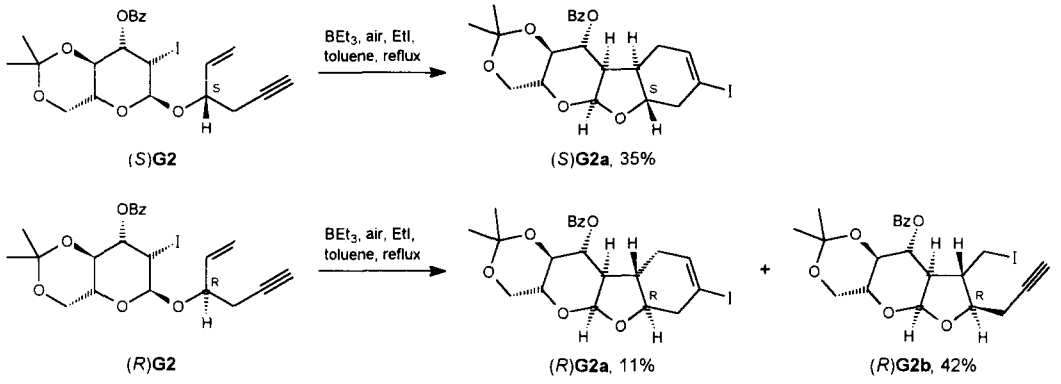


In order to study the conformational flip as postulated in Scheme 4 (***iia*** → ***iib***) we constructed *trans*-fused trioxadecalin systems (*S*)**G2** and (*R*)**G2** (Scheme 6, and Table 1, footnote b). For the (*S*) series there should be no substantial difference in reactivity compared with the cyclization of parent (*S*)**G1**. In the (*R*) series a conformational flip (cf. Scheme 4, ***iia*** → ***iib***) should be more difficult than for monocyclic (*R*)**G1** → (*R*)**G1a** and (*R*)**G1b** (Scheme 3).

In fact, reaction of (*R*)**G2** was broken off after monocyclization to (*R*)**G2b** (42%). The tandem product (*R*)**G2a** was isolated as minor product (11%). The surprising formation of tetracycle (*R*)**G2a** suggests that the tricyclic precursor is not completely rigid, but can adopt a distorted pyranoside chair conformation. The X-ray

crystal structure is in accord with this assumption. In contrast, a well developed pyranoside chair has previously been demonstrated for a cyclization product in the (*S*) series.[10]

Scheme 6. Remote Acetonide Impedes Conformational Flip: (*S*) *vs.* (*R*) Series.



Having studied the effect of conformation and configuration at C(1′) on the cyclization, we turned to the influence of olefin substituents. To this end a number of cyclization precursors were prepared which contained substituents (*E* and also *Z*) at the olefinic terminus. Retention or inversion of configuration can now be studied (Table 3).

Cyclization of (*R,E*)**2** (entry 1) entailed complete retention of *trans*-olefin configuration: the *trans*-configurated hydrogen atoms in starting material (*R,E*)**2** are *trans* to each other in product (*R,E*)**2a**. Similarly, the *trans*-configuration of the double bond in (*S*) diastereomer (*S,E*)**2** was retained in *trans* product (*S,E*)**2a**.

Replacement of the trimethylsilyl group (entry 2) by a methyl group (entry 6) afforded the expected *trans* derived (*S,E*)**3a** in the (*S*) series. In the (*R*) series (entry 5) (*R,E*)**3a** remained the major product (51%). However, leakage into (*R,E*)**3b** with loss of olefin configuration was also discernible (7%). The dioxatriquinane (*R,E*)**3c** (4%) is the result of a kinetic mistake of the first 5-exo-trig cyclization, when all four hydrogen atoms of the central tetrahydrofuran are placed *cis*.[5] The 5-exo-trig, 5-exo-dig cascade is well-known from the Curran hirsutene and $\Delta^{9(12)}$-capnellene synthesis from constrained cyclopentane precursors.[11]

In the (*R*) series the required up-hill conformational flip (Scheme 4, ***iia*** → ***iib***) extends the lifetime of the exocyclic radical, with the concomitant product spread.

Stereoselectivity and complete loss of olefin configuration with terminal methyl group [(*S,Z*)**3** → (*S,E*)**3a**] and a terminal trimethylsilyl group [(*S,Z*)**2** → (*S,E*)**2a**] assumed to be due to the thermodynamic stability of the observed cyclized product. In (*S,E*)**2a** and (*S,E*)**3a** the trimethylsilyl group and the methyl group, respectively, occupy a quasi-equatorial position[10] (entries 4 and 8).

Table 3. Effect of Olefin Configuration and Olefin Substitution on Tricyclic Product in the (*R*)- and (*S*)-Series. All Compounds are Diastereomerically Pure, but Racemic.

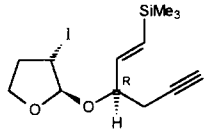
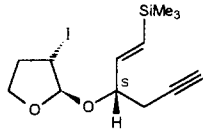
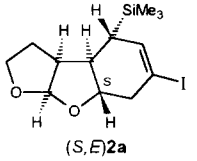
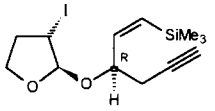
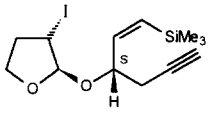
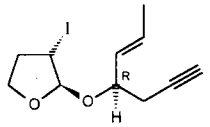
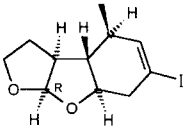
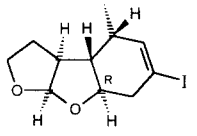
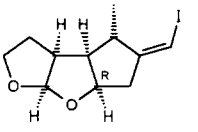
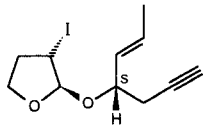
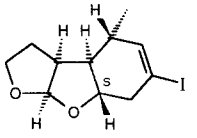
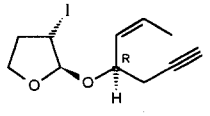
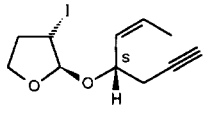
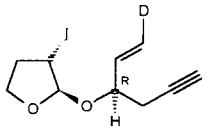
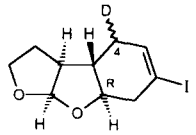
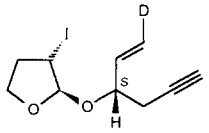
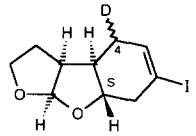
Entry	Educt	Product	Yield [%]
1[a]	 (*R*,*E*)**2**	 (*R*,*E*)**2a**	74[a]
2[b]	 (*S*,*E*)**2**	 (*S*,*E*)**2a**	49
3[b]	 (*R*,*Z*)**2**	(*R*,*E*)**2a**	46
4[b]	 (*S*,*Z*)**2**	(*S*,*E*)**2a**	56
5[c]	 (*R*,*E*)**3**	 (*R*,*E*)**3a**[d],  (*R*,*E*)**3b**[d],  (*R*,*E*)**3c**[d]	51, 7, 4
6[c]	 (*S*,*E*)**3**	 (*S*,*E*)**3a**	70
7[c]	 (*R*,*Z*)**3**	(*R*,*E*)**3a**, (*R*,*E*)**3b**, (*R*,*E*)**3c**	37, 10, 3
8[c]	 (*S*,*Z*)**3**	(*S*,*E*)**3a**	62

Table 3. contd.

9[c]	 (*R,E*)**4**	 (*R,E*)**4a** (1 : 1 mixture of diastereomers)[e]	42
10[c]	 (*S,E*)**4a**	 (*S,E*)**4a** (1 : 1 mixture of diastereomers)[e]	38

[a]Optimized. Method A: BEt_3 (2 eq), EtI (0.25 eq), air, benzene, 80 °C. [b]Method B: BEt_3 (2 eq), EtI (1 eq), air, benzene, 80 °C. [c]Method C: BEt_3 (2 eq), EtI (1 eq), air, toluene, 111 °C. [d]Relative stereochemistry elucidated by NOE. [e]Distinguished by 126 MHz ^{13}C NMR.

A 1 : 1 mixture of diastereomers (with respect to the >CHD centre) was isolated from *trans*-monodeuterated cyclization precursor (*R,E*)**4** and (*S,E*)**4** (entry 9, 10). In this case, thermodynamics favours neither diastereomer and complete scrambling and equilibration of the deuterium label is observed, without any memory of olefin configuration of starting material. Thus, σ-bond rotation in an intermediate radical such as ***ii*** (Scheme 4) and ***v*** (Scheme 5) is much faster than the ensuing 6-endo-dig cyclizationm, in accord with expectation.

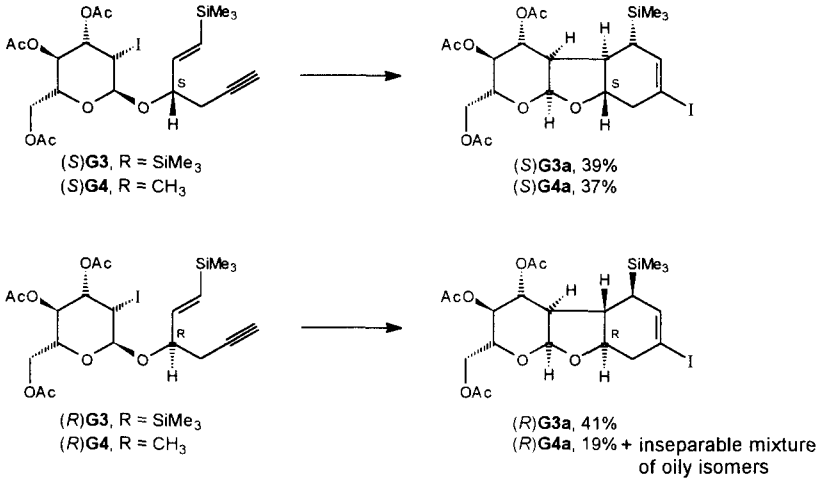
The Trimethylsilyl Effect. The (*R*) configuration of C(1′) necessitates a boat-axial transition state and a conformational flip during the cyclization cascade (Scheme 4, ***iia*** → ***iib***). This disadvantage is usually accompanied by the unselective formation of several products (see above). However, the product spread disappears in the (*R,E*)**2** and also in the (*R,Z*)**2** series (silylated substrates). Apparently, α-silylation facilitates the 5-exo-trig, 6-endo-dig cascade. The trimethylsilyl effect is not a coincidence of the dihydrofuran series. We have also observed it in the carbohydrate series (Scheme 7).

The tandem cyclization is stereoselective in the (*S*) series and also in the epimeric (*R*) series, provided that α-silylation is involved, as in the reaction of carbohydrate derivative (*S*)**G3** and (*R*)**G3**. In contrast, cyclization of the α-methylated precursor (*R*)**G4** was unsatisfactory, giving (*R*)**G4a** in poor yield (19%), in addition to an inseparable mixture of isomers.

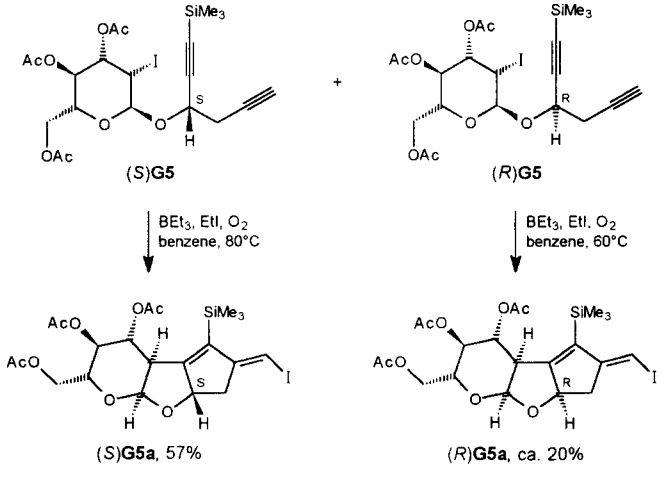
An α-silyl effect was observed earlier by us[12] for another cascade reaction, i. e. the structurally demanding, consecutive 5-exo-dig, 5-exo-dig cyclization (Scheme 8).

In this case, the double annulation was realized only when the reactive vinyl radical intermediate was tamed by α-silyl substitution. Other α-substituents (phenyl, mesityl, *t*-butyl) were not successful. Moreover, in analogy to the enyne systems we observed that the (*S*) precursor (*S*)**G5** afforded tricyclic (*S*)**G5a** in satisfactory yield (57%).

Scheme 7. Enantiopure Glycoconjugates via 5-exo-trig, 6-endo-dig Cascade. Trimethylsilyl *vs.* Methyl Substituent at Olefinic Terminus.



Scheme 8. Rigid, Enantiopure Tricyclic Glycoconjugates *via* Consecutive 5-exo-dig, 5-exo-dig Cycloisomerization.



In the (*R*) series the double cyclization was unsatisfactory, giving (*R*)**G5a** as an unstable product in poor yield (ca. 20%). MMX calculations suggested that the preferentially formed diastereomer (*S*)**G5a** contains a chair like tetrahydropyran ring. It is more stable than nonchair tricycle (*R*)**G5a** by 3.1 kcal/mole. Tricycle (*S*)**G5a** corresponds to (*S*)**G1a**, whereas (*R*)**G5a** corresponds to (*R*)**G1a** (Scheme 3). For the novel 5-exo-dig, 5-exo-dig cascade (Scheme 8) the difference in selectivity of (*S*) and (*R*) series[12] is even more striking than in the 5-exo-trig, 6-endo-dig cascade studied here.

Conclusions. We have investigated scope and limitations of the tandem radical 5-exo-trig, 6-endo-dig reaction. Boat-like, axial transition states for the formation of 5-membered ring are acceptable in the (*R*)-series, given the proper substitution pattern. The initial kinetic error is consolidated by the ensuing irreversible 6-endo-dig cyclization. Substitution of the transient exocyclic radical, which arises from the initial 5-exo-trig cyclization, by α-alkylation and α-silylation is decisive and enhances radical selectivity, nucleophilicity and the yield of tandem product. This effect was also evident in the preparation of polyannulated glycopyranosides.[1] Cyclization substrates, which generate a *primary* radical after the first 5-exo-trig reaction, require the highest reaction temperature (ca. 111 °C) and give the lowest yield of tricyclic product. The intermediate exocyclic radical is essentially free to rotate about the exocyclic carbon-carbon single bond, irrespective of the substitution pattern (7 examples). In the conformationally favourable (*S*) series which involves chair-equatorial transition states, pairs of *E*:*Z* isomers converge on one doubly cyclized product, which is generally formed in good yield. For the epimeric (*R*) series the product spread is characteristic. However, the product spread disappears on silylation of the olefinic terminus. Thus, tricycle (*R,E*)**2a** is formed from precursor (*R,E*)**2** in 74% optimized yield. The concluding 6-endo-dig cyclization, which requires ca. 80 - 110 °C, is an extreme example of radical stereoselectivty and appears to be under full thermodynamic control.

EXPERIMENTAL

General.[1] *General Procedure for the Preparation of Cyclization Precursors via NIS Addition.*[1]

*α-[4′(S)-Hex-5′-en-1′-yn-4′-yl]-3,4,6-tri-*O*-acetyl-2-deoxy-2-iodo-D-mannopyranoside* (*S*)**G1** *and α-[4′(R)-Hex-5′-en-1′-yn-4′-yl]-3,4,6-tri-*O*-acetyl-2-deoxy-2-iodo-D-mannopyranoside* (*R*)**G1**. Glucal (10 mmol) and 1-trimethylsilyl-hex-5-en-1-yn-4-ol were allowed to react according to the general procedure to give silylated precursors (69%), which were separated and desilylated (see preceding paper) to afford (*S*)**G1** (86%) and (*R*)**G1** (80%) as yellowish, honey-like oils. Data for (*S*)**G1**: IR ($CHCl_3$): ν = 3308 cm^{-1}, 3040, 2988, 1744, 1232, 1032, 908; ^1H NMR ($CDCl_3$): δ = 5.89 (ddd, *J* = 7, 10, 18 Hz, 1H; H-5′), 5.47 (s, 1H; H-1), 5.37 (dd, *J* = 9, 9 Hz, 1H; H-4), 5.32 (ddd, *J* = 1, 2, 18 Hz, 1H; H-6′), 5.24 (ddd, *J* = 1, 2, 10 Hz, 1H; H-6′), 4.66 (dd, *J* = 5, 9 Hz, 1H; H-3), 4.60 (dd, *J* = 1, 5 Hz, 1H; H-2), 4.24 (dq, *J* = 1, 7 Hz, 1H; H-4′), 4.20 - 4.14 (m, 1H; H-5), 4.09 (m, 2H; H-6), 2.55 (ddd, *J* = 2, 7, 16 Hz, 1H; H-3′), 2.43 (ddd, *J* = 2, 7, 16 Hz, 1H; H-3′), 2.12 - 2.05 (m, 1H; H-1′), 2.12 (s, 3H; CH_3), 2.09 (s, 3H; CH_3), 2.05 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = C-1′, C-2′, 170.62 (+, C=O), 169.78 (+, C=O), 169.45 (+, C=O), 136.51 (–, C-5′), 117.68 (+, C-6′), 101.00 (–, C-1), 77.89 (–, C-4′), 69.49 (–, C-3), 68.93 (–, C-4), 67.51 (–, C-5), 62.05 (–, C-6), 29.62 (–, C-2), 25.26 (+, C-3′), 20.95 (–, CH_3), 20.72 (–, CH_3), 20.66 (–, CH_3); MS (80 °C, 70 eV): *m/z* (%): 415 (2) [M^+ – 79], 399 (100), 237, 183, 97, 81, 79, 78. Data for (*R*)**G1**: IR (film): ν = 3308 cm^{-1}, 3088, 2988, 1744, 1236, 1032, 908; ^1H NMR ($CDCl_3$): δ = 5.69 (ddd, *J* = 8, 10, 17 Hz, 1H; H-5′), 5.37 (s, 1H; H-1), 5.39 (dd, *J* = 9, 9 Hz, 1H; H-4), 5.31 (dm, *J* = 8 Hz, 1H; H-6′), 5.25 (dm, *J* = 17 Hz, 1H; H-6′), 4.66 (dd, *J* = 5, 9 Hz, 1H; H-3), 4.53 (dd, *J* = 2, 5 Hz, 1H; H-2), 4.28 (m, 1H; H-4′), 4.33 (ddd, *J* = 3, 5, 9 Hz, 1H; H-5), 4.23 (dd, *J* = 5, 12 Hz, 1H; H-6),

4.15 (dd, J = 3, 12 Hz, 1H; H-6) 2.57 (ddd, J = 2, 7, 16 Hz, 1H; H-3′), 2.43 (ddd, J = 2, 6, 16 Hz, 1H; H-3′), 2.13 (s, 3H; CH_3), 2.09 (s, 3H; CH_3), 2.07 (s, 3H; CH_3), 2.04 (t, J = 2 Hz, 1H; H-1′); ^{13}C NMR ($CDCl_3$): δ = 170.60 (+, C=O), 169.74 (+, C=O), 169.45 (+, C=O), 135.02 (–, C-5′), 120.40 (+, C-6′), 98.17 (–, C-1), 80.43 (+, C-2′), 76.62 (–, C-4′), 70.36 (+, C-1′), 69.38 (–, C-3), 69.12 (–, C-4), 67.39 (–, C-5), 62.07 (–, C-6), 29.74 (–, C-2), 25.40 (+, C-3′), 20.93 (–, CH_3), 20.74 (–, CH_3), 20.64 (–, CH_3); MS (120 °C, 70 eV): m/z (%): 494 (2) [M$^+$], 400 (100), 356, 237, 183, 154, 97, 86, 84.

α-[4′(S)-Hex-5′-en-1′-yn-4′-yl]-3-O-benzoyl-4,5-dimethylacetal-2-deoxy-2-iodo-D-mannopyranoside (*S*)**G2** *and α-[4′(R)-Hex-5′-en-1′-yn-4′-yl]-3-O-benzoyl-4,5-dimethylacetal-2-deoxy-2-iodo-D-mannopyranoside* (*R*)**G2**. Preparation see Table 1, footnote *b*. Data for (*S*)**G2**: light-yellow, glassy oil; IR ($CHCl_3$): ν = 3295 cm^{-1}, 3068, 2994, 1725, 1109, 1028, 909; ^{1}H NMR ($CDCl_3$): δ = 8.20 - 8.02 (m, 2H; arom. H), 7.60 - 7.38 (m, 3H; arom. H), 5.90 (ddd, J = 7, 10, 18 Hz, 1H; H-5′), 5.45 (s, 1H; H-1), 5.32 (bd, J = 18 Hz, 1H; H-6′), 5.23 (bd, J = 10 Hz, 1H; H-6′), 4.82 (dd, J = 1, 5 Hz, 1H; H-2), 4.73 (dd, J = 5, 9 Hz, 1H; H-3), 4.35 (dd, J = 9, 10 Hz, 1H; H-4), 4.19 (dq, J = 1, 7 Hz, 1H; H-4′), 4.06 - 3.95 (m, 1H; H-5), 3.89 (dd, J = 2, 12 Hz, 1H; H-6), 3.77 (dd, J = 2, 12 Hz, 1H; H-6) 2.53 (ddd, J = 2, 7, 16 Hz, 1H; H-3′), 2.40 (ddd, J = 2, 6, 16 Hz, 1H; H-3′), 2.07 (t, J = 2 Hz, 1H; H-1′), 1.54 (s, 3H; CH_3), 1.38 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 165.12 (+, C=O), 136.67 (–, C-5′), 133.21 (–, arom. C), 129.90 (–, arom. C), 129.61 (+, arom. C), 128.33 (–, arom. C), 117.32 (–, C-6′), 102.36 (–, C-1), 100.11 (+, C-7), 79.88 (+, C-2′), 77.72 (–, C-4′), 70.93 (–, C-3), 70.63 (+, C-1′), 68.33 (–, C-4), 65.78 (–, C-5), 61.87 (+, C-6), 32.03 (–, C-2), 29.02 (–, CH_3), 25.24 (–, C-3′), 19.19 (–, CH_3); MS (70 °C, 70 eV): m/z (%): 497 (7) [M$^+$ – 15], 105 (100), 101, 79, 77. Data for (*R*)**G2**: light-yellow, glassy oil; IR ($CHCl_3$): ν = 3308 cm^{-1}, 2996, 1720, 1108, 1024, 908; ^{1}H NMR ($CDCl_3$): δ = 8.20 - 8.05 (m, 2H; arom. H), 7.68 - 7.40 (m, 3H; arom. H), 5.68 (ddd, J = 7, 11, 18 Hz, 1H; H-5′), 5.37 (s, 1H; H-1), 5.29 (dm, J = 7 Hz, 1H; H-6′), 5.24 (d, J = 18 Hz, 1H; H-6′), 4.73 (m, 2H; H-2, H-3), 4.35 (dd, J = 9, 10 Hz, 1H; H-4), 4.18 (m, 2H; H-4′, H-5), 3.90 (m, 2H; H-6), 2.60 (ddd, J = 2, 7, 16 Hz, 1H; H-3′), 2.45 (ddd, J = 2, 6, 16 Hz, 1H; H-3′), 2.09 (t, J = 2 Hz, 1H; H-1′), 1.56 (s, 3H; CH_3), 1.38 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 165.28 (+, C=O), 135.19 (–, C-5′), 133.26 (–, arom. C), 129.70 (–, arom. C), 129.26 (+, arom. C), 128.38 (–, arom. C), 120.24 (–, C-6′), 100.20 (+, C-7), 99.47 (–, C-1), 80.22 (+, C-2′), 76.30 (–, C-4′), 71.03 (–, C-3), 70.42 (+, C-1′), 68.54 (–, C-4), 65.75 (–, C-5), 62.23 (+, C-6), 32.12 (–, C-2), 29.90 (–, CH_3), 25.59 (–, C-3′), 19.26 (–, CH_3); MS (70 °C, 70 eV): m/z (%): 497 (2) [M$^+$ – 15], 122, 114, 105 (100), 83, 77.

3(S)-Iodo-2(R)-[6′(E)-trimethylsilyl-1′(R)-prop-3′-ynyl-prop-5′-enyloxy]-tetrahydrofuran (*R,E*)**2** *and 3(S)-Iodo-2(R)-[6′(E)-trimethylsilyl-1′(S)-prop-3′-ynyl-prop-5′-enyloxy]-tetrahydrofuran* (*S,E*)**2**. (*E*)-6-Trimethylsilyl-hex-5-en-1-yn-4-ol (1.80 g, 10.7 mmol), 2,3-dihydropyran (0.50 g, 0.54 ml, 7.1 mmol) and NIS (2.40 g, 10.7 mmol) were allowed to react according to the general procedure to afford after chromatography (E/PE, 1 : 50) (*R,E*)**2** (1.15 g) and (*S,E*)**2** (1.19 g) (91% altogether) as colourless oils. Data for (*R,E*)**2**: IR (film): ν = 3307 cm^{-1}, 2940, 2122, 1620, 1249, 1010, 867; ^{1}H NMR ($CDCl_3$): δ = 5.95 (dd, J = 6.5, 18 Hz, 1H; H-5′), 5.85 (d, J = 18 Hz, 1H; H-6′), 5.50 (s, 1H; H-2), 4.24 (dd, J = 2, 6 Hz, 1H; H-3), 4.20 - 4.00 (m, 3H; H-1′, H-5), 2.80 - 2.60 (m, 1H; H-4), 2.40 (dd, J = 2.5, 6.5 Hz, 2H; H-2′), 2.25 - 2.10 (m, 1H; H-4), 2.00 (t, J = 2.5 Hz, 1H; H-4′), 0.05 (s, 9H; $SiMe_3$); ^{13}C NMR ($CDCl_3$): δ = 144.14 (–, C-5′), 131.56 (–, C-6′), 100.40 (–, C-2), 80.51 (+, C-3′), 76.70 (–, C-1′), 70.06 (+, C-4′), 67.07 (+, C-5), 35.03 (+, C-4), 25.03 (–, C-3), 24.92 (+, C-2′), –1.41 (–, $SiMe_3$); MS (70 eV): m/z (%): 325 (2) [M$^+$ – 39], 252 (2), 197 (100), 168 (28), 70 (79). Data for (*S,E*)**2**: ^{1}H NMR ($CDCl_3$): δ = 5.95 (d, J = 18 Hz, 1H; H-6′), 5.85 (d, J = 6.5, 18 Hz, 1H; H-5′),

5.30 (s, 1H; H-2), 4.24 - 4.00 (m, 4H; H-1′, H-3, H-5), 2.80 - 2.55 (m, 1H; H-4), 2.46 - 2.36 (m, 2H; H-2′), 2.27 - 2.12 (m, 1H; H-4), 1.95 (t, J = 2.5 Hz, 1H; H-4′), 0.10 (s, 9H; $SiMe_3$); ^{13}C NMR ($CDCl_3$): δ = 142.96 (–, C-5′), 134.66 (–, C-6′), 107.76 (–, C-2), 80.65 (+, C-3′), 76.89 (–, C-1′), 69.64 (+, C-4′), 66.96 (+, C-5), 35.70 (+, C-4), 25.69 (–, C-2′), 24.89 (+, C-3), –0.03 (–, $SiMe_3$); MS (70 eV): *m/z* (%): 267 (9) [M^+ – 39], 197 (100), 93, 91, 77, 70.

3(S)-Iodo-2(R)-[6′(Z)-trimethylsilyl-1′(R)-prop-3′-ynyl-prop-5′-enyloxy]-tetrahydrofuran (*R,Z*)**2** *and 3(S)-Iodo-2(R)-[6′(Z)-trimethylsilyl-1′(S)-prop-3′-ynyl-prop-5′-enyloxy]-tetrahydrofuran* (*S,Z*)**2**. (*Z*)-6-Trimethylsilyl-hex-5-en-1-yn-4-ol (0.50 g, 2.97 mmol), 2,3-dihydropyran (104 mg, 0.11 ml, 1.49 mmol) and NIS (0.26 g, 2.24 mmol) were allowed to react according to the general procedure to afford after chromatography (E/PE, 1 : 20) (*R,Z*)**2** (112 mg) and (*S,Z*)**2** (104 mg) (40% altogether) as colourless oils. Data for (*R,Z*)**2**: ^1H NMR ($CDCl_3$): δ = 6.08 (dd, J = 9, 14 Hz, 1H; H-5′), 5.87 (d, J = 14 Hz, 1H; H-6′), 5.34 (s, 1H; H-2), 4.38 (dt, J = 6, 9 Hz, 1H; H-1′), 4.18 - 4.00 (m, 3H; H-5), 2.88 - 2.58 (m, 1H; H-4), 2.45 (ddd, J = 2.5, 6, 17 Hz, 1H; H-2′), 2.33 (ddd, J = 2.5, 6, 17 Hz, 1H; H-2′), 2.20 (dddd, J = 2, 4, 6.5, 14 Hz, 1H; H-4), 1.97 (t, J = 2.5 Hz, 1H; H-4′), 0.18 (s, 9H; $SiMe_3$); MS (70 eV): *m/z* (%): 325 (3) [M^+ – 39], 285 (2), 197 (100), 167 (3). HRMS calcd. for $C_{10}H_{18}O_2ISi$: 325.0121, found 325.0114. Data for (*S,Z*)**2**: IR ($CHCl_3$): ν = 3308 cm^{-1}, 3000, 2956, 2100, 1248, 1012, 840; ^1H NMR ($CDCl_3$): δ = 6.18 (dd, J = 9, 14 Hz, 1H; H-5′), 5.73 (dd, J = 0.5, 14 Hz, 1H; H-6′), 5.49 (s, 1H; H-2), 4.32 (ddt, J = 0.5, 6, 9 Hz, 1H; H-1′), 4.20 (dd, J = 2, 5.5 Hz, 1H; H-3), 4.14 - 3.95 (m, 2H; H-5), 2.70 - 2.50 (m, 1H; H-4), 2.45 (ddd, J = 2.5, 6, 17 Hz, 1H; H-2′), 2.34 (ddd, J = 2.5, 6, 17 Hz, 1H; H-2′), 2.23 (dddd, J = 2, 4, 6.5, 16 Hz, 1H; H-4), 2.00 (t, J = 2.5 Hz, 1H; H-4′), 0.16 (s, 9H; $SiMe_3$); ^{13}C NMR ($CDCl_3$): δ = 145.94 (–, C-5′), 132.84 (–, C-6′), 108.84 (–, C-2), 80.25 (+, C-3′), 74.91 (–, C-1′), 70.22 (+, C-4′), 67.07 (+, C-5), 35.16 (+, C-4), 25.35 (–, C-2′), 25.21 (+, C-3), 0.26 (–, $SiMe_3$).

*3(S)-Iodo-2(R)[1′(R)-prop-3′-ynyl-*trans*-prop-5′-enyloxy]-tetrahydrofuran* (*R,E*)**3** *and 3(S)-Iodo-2(R)-[1′(S)-prop-3′-ynyl-*trans*-prop-5′-enyloxy]-tetrahydrofuran* (*S,E*)**3**. 1-Trimethylsilyl-hept-5-*trans*-en-1-yn-4-ol and 2,3-dihydropyran (5.3 mmol) were allowed to react according to the general procedure to give silylated precursors (65%), which were separated and desilylated to afford after desilylation (*R,E*)**3** (95%) and (*S,E*)**3** (92%) as yellowish oils. Data for (*R,E*)**3**: IR ($CHCl_3$): ν = 3296 cm^{-1}, 2941, 2916, 2122, 1671, 1085, 1008, 969; ^1H NMR ($CDCl_3$): δ = 5.77 (ddq, J = 0.6, 6, 15 Hz, 1H; H-6′), 5.37 (s, 1H; H-2), 5.33 (ddq, J = 2, 8, 15 Hz, 1H; H-5′), 4.23 - 3.99 (m, 4H; H-1′, H-3, H-5), 2.69 (ddd, J = 6, 8, 14 Hz, 1H; H-4), 2.44 (ddd, J = 2, 6, 16 Hz, 1H; H-2′), 2.34 (ddd, J = 2, 6, 16 Hz, 1H; H-2′), 2.20 (dddd, J = 2, 4, 8, 14 Hz, 1H; H-4), 1.97 (t, J = 3 Hz, 1H; H-4′), 1.74 (dd, J = 2, 6 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 131.00 (–, C-5′), 129.00 (–, C-6′), 107.00 (–, C-2), 80.82 (+, C-3′), 74.45 (–, C-1′), 69.51 (+, C-4′), 66.80 (+, C-5), 35.57 (+, C-4), 25.69 (+, C-2′), 25.23 (–, C-3), 17.75 (–, CH_3); MS (70 eV): *m/z* (%): 267 (5) [M^+ – 39], 197 (100), 93, 91, 77, 70, 69. Data for (*S,E*)**3**: IR ($CHCl_3$): ν = 3295 cm^{-1}, 2937, 2916, 2121, 1673, 1088, 1010, 967; ^1H NMR ($CDCl_3$): δ = 5.72 (ddq, J = 0.6, 6, 15 Hz, 1H; H-6′), 5.51 (s, 1H; H-2), 5.47 (ddq, J = 2, 6, 15 Hz, 1H; H-5′), 4.24 (dd, J = 2, 6 Hz, 1H; H-3), 4.18 - 4.00 (m, 3H; H-1′, H-5), 3.63 (ddd, J = 6, 8, 14 Hz, 1H; H-4), 2.46 (ddd, J = 2, 6, 16 Hz, 1H; H-2′), 2.35 (ddd, J = 2, 6, 16 Hz, 1H; H-2′), 2.19 (dddd, J = 2, 4, 8, 14 Hz, 1H; H-4), 2.03 (t, J = 2 Hz, 1H; H-4′), 1.72 (dq, J = 0.6, 6 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 130.02 (–, C-5′), 128.61 (–, C-6′), 107.09 (–, C-2), 80.63 (+, C-3′), 69.38 (+, C-4′), 68.37 (–, C-1′), 66.78 (+, C-5), 35.57 (+, C-4), 25.58 (+, C-2′), 25.12 (–, C-3), 13.49 (–, CH_3); MS (70 eV): *m/z* (%): 267 (9) [M^+ – 39], 197 (100), 93, 91, 77, 70.

3(S)-Iodo-2(R)-[1′(R)-prop-3′-ynyl-cis-*prop-5′-enyloxy]-tetrahydrofuran* (*R,Z*)**3** *and 3(S)-Iodo-2(R)-[1′(S)-prop-3′-ynyl*-cis-*prop-5′-enyloxy]-tetrahydrofuran* (*S,E*)**3**. 1-Trimethylsilyl-hept-5-*cis*-en-1-yn-4-ol and 2,3-dihydropyran (5.3 mmol) were allowed to react according to the general procedure to give silylated precursors (49%), which were separated and desilylated to afford after desilylation (*R,Z*)**3** (86%) and (*S,Z*)**3** (89%) as yellowish oils. Data for (*R,Z*)**3**: IR ($CHCl_3$): ν = 3296 cm^{-1}, 3012, 2976, 1084, 1040, 1004, 916; ^1H NMR ($CDCl_3$): δ = 5.80 (ddq, *J* = 1, 6, 11 Hz, 1H; H-6′), 5.32 (s, 1H; H-2), 5.27 (ddq, *J* = 2, 10, 11 Hz, 1H; H-5′). 4.62 (ddt, *J* = 1, 6, 10 Hz, 1H; H-1′), 4.20 - 3.99 (m, 3H; H-3, H-5), 2.69 (ddd, *J* = 6, 8, 14 Hz, 1H; H-4), 2.45 (ddd, *J* = 2, 6, 16 Hz, 1H; H-2′), 2.32 (ddd, *J* = 2, 6, 16 Hz, 1H; H-2′), 2.19 (ddm, *J* = 4, 14 Hz, 1H; H-4), 1.97 (t, *J* = 2 Hz, 1H; H-4′), 1.74 (dd, *J* = 2, 6 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 131.00 (–, C-5′), 129.00 (–, C-6′), 107.00 (–, C-2), 80.82 (+, C-3′), 74.45 (–, C-1′), 69.51 (+, C-4′), 66.80 (+, C-5), 35.57 (+, C-4), 25.69 (+, C-2′), 25.23 (–, C-3), 17.75 (–, CH_3); MS (70 eV): *m/z* (%): 267 (5) [M^+ – 39], 197 (100), 93, 91, 77, 70, 69. Data for (*S,Z*)**3**: IR ($CHCl_3$): ν = 3296 cm^{-1}, 3080, 3016, 2932, 2120, 1084, 1020, 920; ^1H NMR ($CDCl_3$): δ = 5.68 (ddq, *J* = 1, 7, 11 Hz, 1H; H-6′), 5.51 (s, 1H; H-2), 5.41 (ddq, *J* = 2, 10, 11 Hz, 1H; H-5′), 4.55 (ddt, *J* = 1, 6, 10 Hz, 1H; H-1′), 4.22 (dd, *J* = 2, 6 Hz, 1H; H-3), 4.14 - 3.95 (m, 2H; H-5), 2.62 (ddd, *J* = 6, 8, 14 Hz, 1H; H-4), 2.47 (ddd, *J* = 2, 6, 16 Hz, 1H; H-2′), 2.34 (ddd, *J* = 2, 6, 16 Hz, 1H; H-2′), 2.18 (dddd, *J* = 2, 4, 6, 14 Hz, 1H; H-4), 2.01 (t, *J* = 2 Hz, 1H; H-4′), 1.72 (dd, *J* = 2, 7 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 129.77 (–, C-5′), 127.73 (–, C-6′), 109.09 (–, C-2), 80.46 (+, C-3′), 70.35 (–, C-1′), 69.89 (+, C-4′), 67.04 (+, C-5), 35.24 (+, C-4), 25.17 (+, C-2′), 25.20 (–, C-3), 13.41 (–, CH_3); MS (70 eV): *m/z* (%): 267 (10) [M^+ – 39], 197 (100), 93, 91, 77, 71, 70, 69.

*3(S)-Iodo-2(R)-[*trans-*6′-deutero-1′(R)-prop-3′-ynyl-prop-5′-enyloxy]-tetrahydrofuran* (*R,E*)**4** *and 3(S)-Iodo-2(R)-[*trans-*6′-deutero-1′(S)-prop-3′-ynyl-prop-5′-enyloxy]-tetrahydrofuran* (*S,E*)**4**. *trans*-6-Deutero-hex-5-en-1-yn-4-ol and 2,3-dihydropyran (7.8 mmol) were allowed to react according to the general procedure to afford (*R,E*)**4** and (*S,E*)**4** (51% altogether) as yellowish oils. Data for (*R,E*)**4**: IR ($CHCl_3$): ν = 3296 cm^{-1}, 2947, 2896, 2122, 1624, 1085, 1012, 921; ^1H NMR ($CDCl_3$): δ = 5.73 (dd, *J* = 8, 17 Hz, 1H; H-6′), 5.36 (s, 1H; H-2), 5.30 (dd, *J* = 1, 17 Hz, 1H; H-5′), 4.24 - 4.00 (m, 4H; H-1′, H-3, H-5), 2.69 (dddd, *J* = 1, 6, 8, 14 Hz, 1H; H-4), 2.47 (ddd, *J* = 2, 6, 18 Hz, 1H; H-2′), 2.36 (ddd, *J* = 2, 6, 18 Hz, 1H; H-2′), 2.20 (dddd, *J* = 2, 4, 8, 14 Hz, 1H; H-4), 2.00 (t, *J* = 2 Hz, 1H; H-4′); ^{13}C NMR ($CDCl_3$): δ = 135.80 (–, C-5′), 118.97/118.50/118.01 (–, C-6′), 107.34 (–, C-2), 80.53 (+, C-3′), 74.61 (–, C-1′), 69.08 (+, C-4′), 66.78 (+, C-5), 35.49 (+, C-4), 25.68 (+, C-2′), 24.78 (–, C-3); MS (70 eV): *m/z* (%): 294 (0.01) [M^+ +1], 293 (0.6) [M^+], 254, 198, 197 (100), 196, 80, 79, 78, 77, 70. Data for (*S,E*)**4**: IR ($CHCl_3$): ν = 3295 cm^{-1}, 2896, 2121, 1625, 1087, 1013, 921; ^1H NMR ($CDCl_3$): δ = 5.89 (dd, *J* = 6, 17 Hz, 1H; H-6′), 5.52 (s, 1H; H-2), 5.27 (dd, *J* = 1, 17 Hz, 1H; H-5′), 4.24 (dd, *J* = 2, 6 Hz, 1H; H-3), 4.22 - 3.98 (m, 3H; H-1′, H-5), 2.65 (dddd, *J* = 1, 6, 8, 13 Hz, 1H; H-4), 2.51 (ddd, *J* = 2, 6, 14 Hz, 1H; H-2′), 2.38 (ddd, *J* = 2, 6, 14 Hz, 1H; H-2′), 2.19 (dddd, *J* = 2, 4, 9, 13 Hz, 1H; H-4), 2.03 (t, *J* = 2 Hz, 1H; H-4′); ^{13}C NMR ($CDCl_3$): δ = 137.10 (–, C-5′), 116.64/116.16/115.68 (–, C-6′), 109.48 (–, C-2), 80.37 (+, C-3′), 75.69 (–, C-1′), 70.22 (+, C-4′), 67.15 (+, C-5), 35.32 (+, C-4), 25.12 (+, C-2′), 25.00 (–, C-3); MS (70 eV): *m/z* (%):291 (0.1) [M^+ – 1], 254, 213, 198, 197 (100), 196, 168, 80, 79, 78.

*α-[4′(S)-Hept-*trans-*5′-en-1′-yn-4′-yl]-3,4,6-tri-*O*-acetyl-2-deoxy-2-iodo-D-mannopyranoside* (*S*)**G4** *and α-[4′(R)-Hept-*trans-*5′-en-1′-yn-4′-yl]-3,4,6-tri-*O*-acetyl-2-deoxy-2-iodo-D-mannopyranoside* (*R*)**G4**. Glucal (3.8 mmol) and 1-trimethylsilyl-hept-5-*trans*-en-1-yn-4-ol were allowed to react according to the

general procedure to give silylated precursors (71%), which were separated and desilylated (see preceding paper) to afford (*S*)**G4** (71%) and (*R*)**G4** (62%) as yellowish, honey-like, viscous oils. Data for (*S*)**G4**: IR (film): ν = 3289 cm^{-1}, 2940, 2121, 1747, 1230, 1044, 916; ^{1}H NMR ($CDCl_3$): δ = 5.70 (dq, *J* = 6, 15 Hz, 1H; H-6′), 5.50 (ddq, *J* = 1, 8, 15 Hz, 1H; H-5′), 5.42 (s, 1H; H-1), 5.38 (dd, *J* = 9, 9 Hz, 1H; H-4), 4.67 (dd, *J* = 5, 9 Hz, 1H; H-3), 4.57 (d, *J* = 5 Hz, 1H; H-2), 4.21 (dd, *J* = 5, 12 Hz, 1H; H-6), 4.16 (m, 1H; H-4′), 4.13 (m, 1H; H-5), 4.05 (dd, *J* = 3, 12 Hz, 1H; H-6), 2.50 (ddd, *J* = 3, 8, 18 Hz, 1H; H-3′), 2.41 (ddd, *J* = 3, 8, 18 Hz, 1H; H-2′), 2.12 (s, 3H; CO_2CH_3), 2.10 (s, 3H; CO_2CH_3), 2.06 (s, 3H; CO_2CH_3), 2.02 (t, *J* = 3 Hz, 1H; H-1′), 1.54 (dd, *J* = 1, 6 Hz, 3H; CH_3), ^{13}C NMR ($CDCl_3$): δ = 170.66 (+, C=O), 169.81 (+, C=O), 169.47 (+, C=O), 129.74 (–, C-5′), 129.58 (–, C-6′), 100.94 (–, C-1), 80.17 (+, C-2′), 77.49 (–, C-4′), 70.40 (+, C-1′), 70.40 (–, C-3), 69.04 (–, C-4), 67.66 (–, C-5), 62.13 (+, C-6), 29.90 (–, C-2), 25.59 (+, C-3′), 20.95 (–, $CO(CH_3)$), 20.72 (–, $CO(CH_3)$), 20.66 (–, $CO(CH_3)$), 17.71 (CH_3); FAB-MS (70 eV): *m/z*: 509 [M$^+$ + 1], 399. Data for (*R*)**G4**: IR (film): ν = 3289 cm^{-1}, 2941, 2122, 1747, 1229, 1045, 915; ^{1}H NMR ($CDCl_3$): δ = 5.79 (dq, *J* = 6, 15 Hz, 1H; H-6′), 5.50 (ddq, *J* = 2, 9, 15 Hz, 1H; H-5′), 5.41 (dd, *J* = 9, 9 Hz, 1H; H-4), 5.20 (s, 1H; H-1), 4.66 (dd, *J* = 5, 9 Hz, 1H; H-3), 4.51 (dd, *J* = 2, 5 Hz, 1H; H-2), 4.31 (ddd, *J* = 3, 5, 9 Hz, 1H; H-5), 4.24 (dd, *J* = 5, 12 Hz, 1H; H-6), 4.16 (dd, *J* = 3, 12 Hz, 1H; H-6), 4.12 (m, 1H; H-4′), 2.52 (ddd, *J* = 6, 8, 16 Hz, 1H; H-3′), 2.40 (ddd, *J* = 3, 6, 16 Hz, 1H; H-2′), 2.14 (s, 3H; CO_2CH_3), 2.10 (s, 3H; CO_2CH_3), 2.07 (s, 3H; CO_2CH_3), 2.00 (t, *J* = 3 Hz, 1H; H-1′), 1.75 (dd, *J* = 1, 6 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 170.65 (+, C=O), 169.77 (+, C=O), 169.48 (+, C=O), 132.65 (–, C-6′), 128.03 (–, C-5′), 97.68 (–, C-1), 80.08 (+, C-2′), 76.18 (–, C-4′), 70.00 (+, C-1′), 70.00 (–, C-3), 70.00 (–, C-4), 69.26 (–, C-5), 62.15 (+, C-6), 30.11 (–, C-2), 25.73 (+, C-3′), 20.92 (–, $CO(CH_3)$), 20.72 (–, $CO(CH_3)$), 20.61 (–, $CO(CH_3)$), 17.71 (CH_3); FAB-MS (70 eV): *m/z*: 509 [M$^+$ + 1], 399.

*General Procedure for the Cyclization with BEt_3 catal. O_2 EtI. Optimized Method A (applied to (R,E)***2***).* A flame-dried two-necked flask equipped with reflux condenser, $CaCl_2$ drying tube and septum was charged with cyclization precursor in abs. benzene (0.5 M) under dry air atmosphere. EtI (0.25 eq) was added and the mixture was heated to reflux. BEt_3 (2 eq, 1 M in hexane) from a fresh opened bottle was added dropwise within 10 min. The reaction was monitored by TLC (for cyclizations on a >1 mmol scale dry air from a balloon was blown through the reaction flask every 10 min for a few sec.). After complete reaction the mixture was cooled to r.t., the solvent removed and the crude product purified by chromatography. *Method B*. BEt_3 (2 eq), EtI (1 eq) and cyclization precursor in benzene were allowed to react as described for Method A. *Method C*. BEt_3 (2 eq), EtI (1 eq) and cyclization precursor in toluene were allowed to react as described for Method A.

2(R),3(S),4(R),4a(R),4b(R),8a(S),9a(S)-2-Acetoxymethyl-7-iodo-3,4,4a,4b,5,8,8a,9a-octahydro-2H-pyrano[2,3-b]benzofuran-3,4-diol Diacetate (*S*)**G1a**. Precursor (*S*)**G1** (5.2 mmol) was allowed to react according to method B to give (*S*)**G1a** (36%) as colourless crystals, m.p. 169 °C, $[\alpha]_D^{20}$ = 156.8° (*c* = 0.95 in CH_2Cl_2). IR (KBr): ν = 2928 cm^{-1}, 1747, 1367, 1246, 1044; ^{1}H NMR ($CDCl_3$): δ = 5.89 (bt, *J* = 3 Hz, 1H; H-6), 5.28 (d, *J* = 5 Hz, 1H; H-9a), 5.18 (dd, *J* = 9, 10 Hz, 1H; H-3), 5.05 (dd, *J* = 9, 9 Hz, 1H; H-4), 4.54 (dd, *J* = 4, 12 Hz, 1H; H-10), 4.01 (dd, *J* = 2, 12 Hz, 1H; H-10), 3.84 (ddd, *J* = 2, 4, 10 Hz, 1H; H-2), 3.25 (ddd, *J* = 6, 10, 11 Hz, 1H; H-8a), 2.76 (dd, *J* = 6, 16 Hz, 1H; H-8), 2.31 (dddd, *J* = 2, 4, 11, 16 Hz, 1H; H-8), 1.87 (dt, *J* = 5, 9 Hz, 1H; H-4a), 1.74 (m, 1H; H-5), 1.47 (ddt, *J* = 2, 3, 17 Hz, 1H; H-5), 1.20 (ddd, *J* = 5, 6, 11 Hz, 1H; H-4b), 1.78 (s, 3H; CH_3), 1.75 (s, 3H; CH_3), 1.73 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 170.05 (+, C=O), 169.80 (+, C=O), 169.60 (+, C=O), 136.81 (–, C-6), 102.31 (–, C-9a), 91.92 (+, C-7), 77.52 (–, C-8a), 69.84

(–, C-4), 69.45 (–, C-3), 68.77 (–, C-2), 61.86 (+, C-10), 46.96 (+, C-8), 43.89 (–, C-4a), 41.25 (–, C-4b), 28.35 (–, C-5), 20.59 (–, CH_3), 20.39 (–, CH_3), 20.33 (–, CH_3); MS (130 °C, 70 eV): *m/z* (%): 495 (1.4) [M^+ + 1], 494 (3) [M^+], 374, 313, 222, 213 (100), 205, 204, 187, 153, 111, 95, 94, 91.

2(R),3(S),4(R),4a(R),4b(S),8a(R),9a(S)-2-Acetoxymethyl-7-iodo-3,4,4a,4b,5,8,8a,9a-octahydro-2H-pyrano[2,3-b]benzofuran-3,4-diol Diacetate (*R*)**G1a** *and 5-(4′-Iodomethyl)-6-prop-2-ynylhexahydro-4(R),5(S)-diacetoxy-6(S)-2-acetoxymethylpyrano[2,3-b]furan* (*R*)**G1b**. Precursor (*R*)**G1** (0.06 mmol) was allowed to react according to method B to give (*R*)**G1a** and (*R*)**G1b**. Data for (*R*)**G1a**: yield 21%, light-yellow, glassy oil, $[\alpha]_D^{20} = -14.5°$ (*c* = 1.15 in CH_2Cl_2). IR (KBr): ν = 3040 cm^{-1}, 2956, 1744, 1368, 1232, 1036; ^1H NMR ($CDCl_3$): δ = 5.89 (m, 1H; H-6), 5.37 (d, *J* = 6 Hz, 1H; H-9a), 5.21 (d, *J* = 9 Hz, 1H; H-3), 5.08 (dd, *J* = 1, 1 Hz, 1H; H-4), 4.31 (d, *J* = 4, 2H; H-10), 4.02 (dt, *J* = 4, 9 Hz, 1H; H-2), 2.99 (ddd, *J* = 6, 10, 10 Hz, 1H; H-8a), 2.86 (dd, *J* = 4, 16 Hz, 1H; H-8), 2.57 (m, 1H; H-8), 2.01 - 1.79 (m, 1H; H-4a), 2.01 (dm, *J* = 16 Hz, 1H; H-5), 1.42 (dm, *J* = 16 Hz, 1H; H-5), 1.79 - 1.54 (m, 1H; H-4b), 1.67 (s, 3H; CH_3), 1.65 (s, 3H; CH_3), 1.59 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 170.70 (+, C=O), 169.15 (+, C=O), 169.07 (+, C=O), 136.70 (–, C-6), 99.50 (–, C-9a), 92.36 (+, C-7), 77.76 (–, C-8a), 70.91 (–, C-4), 69.63 (–, C-3), 67.50 (–, C-2), 63.30 (+, C-10), 45.75 (+, C-8), 45.69 (–, C-4a), 41.04 (–, C-4b), 32.22 (–, C-5), 20.27 (–, CH_3), 20.27 (–, CH_3), 20.15 (–, CH_3); MS (100 °C, 70 eV): *m/z* (%):494 (0.6) [M^+], 269, 236, 209, 193, 167 (100), 164, 136, 82. Data for (*R*)**G1b**: yield 6%, caramel-like oil, $[\alpha]_D^{20} = 25.0°$ (*c* = 2.7 in CH_2Cl_2). IR ($CHCl_3$): ν = 3308 cm^{-1}, 3040, 2956, 1744, 1232, 1048, 924; ^1H NMR ($CDCl_3$): δ = 5.40 (dd, *J* = 9, 10 Hz, 1H; H-3), 5.24 (dd, *J* = 9, 10 Hz, H-4), 4.99 (d, *J* = 5 Hz, 1H; H-7a), 4.44 (dd, *J* = 4, 12 Hz, 1H; H-8), 4.08 (dd, *J* = 2, 12 Hz, 1H; H-8), 4.19 (ddd, *J* = 2, 4, 10 Hz, 1H; H-2), 3.09 (ddd, *J* = 5, 10, 10 Hz, 1H; H-6), 2.60 (dd, *J* = 4, 14 Hz, 1H; H-4′), 2.45 - 2.20 (m, 4H; H-5, H-3′, H-4′), 1.88 (t, *J* = 3 Hz, 1H; H-1′), 1.86 (ddd, *J* = 2, 5, 10 Hz, 1H; H-4a), 1.76 (s, 3H; CH_3), 1.74 (s, 3H; CH_3), 1.70 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 170.07 (+, C=O), 170.03 (+, C=O), 169.35 (+, C=O), 99.40 (–, C-7a), 79.02 (+, C-2′), 78.90 (–, C-6), 72.90 (–, C-4), 71.65 (+, C-1′), 70.40 (–, C-3), 68.41 (–, C-2), 61.94 (+, C-8), 49.11 (–, C-4a), 48.38 (–, C-5), 24.47 (+, C-3′), 20.53 (–, CH_3), 20.35 (–, CH_3), 20.27 (–, CH_3), 7.48 (+, C-4′); MS (100 °C, 70 eV): *m/z* (%): 455 (3) [M^+ – 39], 395, 293, 84 (100), 82.

4a(R),4b(R),5(R),5b(S),9a(R),10a(S),11a(S)-Benzoic Acid, 2-Iodo-7,7-dimethyl-1,4,4a,5,5a,9a,10a,11a-decahydro-6,8,10,11-tetraoxa-benzo[b]fluoren-5-yl Ester (*S*)**G2a**. Precursor (*S*)**G2** (0.57 mmol) was allowed to react according to the method C to give(*S*)**G2a** (35%) as colourless crystals, m.p. 224 °C, $[\alpha]_D^{20} = 115.7°$ (*c* = 1.1 in CH_2Cl_2). IR ($CHCl_3$): ν = 2899 cm^{-1}, 1724, 1268, 1108, 1044, 944; ^1H NMR ($CDCl_3$): δ = 8.11 - 8.00 (m, 2H; arom. H), 7.65 - 7.41 (m, 3H; arom. H), 6.23 (m, 1H; H-3), 5.63 (d, *J* = 5 Hz, H-10a), 5.33 (dd, *J* = 8, 10 Hz, 1H; H-5), 4.25 (ddd, *J* = 6, 10, 10 Hz, 1H; H-11a), 3.97 (ddd, *J* = 3, 5, 10 Hz, 1H; H-9a), 3.88- 3.65 (m, 3H; H-5a, H-9), 3.07 (dd, *J* = 6, 16 Hz, 1H; H-1), 2.71 - 2.52 (m, 1H; H-1),2.62 (ddd, *J* = 5, 6, 10 Hz, 1H; H-4b), 2.21 (dm, *J* = 16 Hz, 1H; H-4), 2.12 (m, 1H; H-4a), 2.02 (dm, *J* = 16 Hz, 1H; H-4), 1.42 (s, 3H; CH_3), 1.33 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 165.14 (+, C=O), 136.98 (–, C-3), 133.17 (–, arom. C), 129.84 (+, arom. C), 129.62 (–, arom. C), 128.40 (–, arom. C), 102.64 (–, C-10a), 99.57 (+, C-7), 90.84 (+, C-2), 78.01 (–, C-11a), 71.94 (–, C-5), 69.16 (–, C-5a), 64.24 (+, C-9a), 61.86 (+, C-9), 46.30 (+, C-1), 44.07 (–, C-4b), 41.73 (–, C-4a), 28.81 (–, CH_3), 28.43 (+, C-4), 18.88 (–, CH_3); MS (70 eV): *m/z* (%): 513 (10) [M^+ +1], 512 (32) [M^+], 497, 454, 453 (100), 106, 101, 95, 91, 77. X-ray crystal structure see ref. 10

4a(S),4b(R),5(R),5b(S),9a(R),10a(S),11a(R)-Benzoic acid, 2-Iodo-7,7-dimethyl-1,4,4a,5,5a,9a,10a,11a-decahydro-6,8,10,11-tetraoxa-benzo[b]fluoren-5-yl Ester (*R*)**G2a** *and 2(R),3(R),3a(R),4(R),4a(S),8a(R),9a(S)-Benzoic Acid, 6,6-Dimethyl-3-(4′-iodomethyl)-2-prop-2′-ynyl-1,2,3,3a,4,4a,8,8a,9a-nonahydro-1,5,7,9-tetraoxa-benzo[b]inden-4-yl Ester* (*R*)**G2b** Precursor (*R*)**G2** (0.06 mmol) was allowed to react according to the method C to give (*R*)**G2a** and (*R*)**G2b**. Data for (*R*)**G2a**: yield 11%, colourless crystals, m.p. 189 °C, $[\alpha]_D^{20}$ = −56.8° (*c* = 1.2 in CH_2Cl_2); IR ($CHCl_3$): ν = 2993 cm^{-1}, 1723, 1602, 1267, 1108, 714; ^1H NMR ($CDCl_3$): δ = 8.04 (m, 2H; arom. H), 7.60 (m, 1H; arom. H), 7.46 (m, 2H; arom. H), 5.53 (d, *J* = 7 Hz, H-10a), 5.37 (m, 1H; H-3), 5.09 (dd, *J* = 2, 7 Hz, 1H; H-5), 4.05 (dd, *J* = 7, 10 Hz, 1H; H-5a), 4.02 (d, *J* = 10 Hz, 1H; H-9), 3.78 (dd, *J* = 10, 10 Hz, 1H; H-9), 3.67 (m, 1H; H-9a), 3.44 (ddd, *J* = 5, 10, 10 Hz, 1H; H-11a), 3.01 (ddm, *J* = 5, 16 Hz, 1H; H-1), 2.80 (m, 2H; H-4, H-4b), 2.15 (m, 1H; H-1), 2.05-1.83 (m, 2H; H-4, H-4a), 1.51 (s, 3H; CH_3), 1.39 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 165.87 (+, C=O), 137.08 (–, C-3), 133.31 (–, arom. C), 129.76 (+, arom. C), 129.66 (–, arom. C), 128.46 (–, arom. C), 99.84 (+, C-7), 99.79 (–, C-10a), 91.48 (+, C-2), 76.29 (–, C-11a), 73.93 (–, C-5), 72.12 (–, C-5a), 62.84 (+, C-9a), 62.63 (+, C-9), 48.41 (–, C-4b), 46.09 (–, C-4a), 45.48 (+, C-1), 32.85 (+, C-4), 28.92 (–, CH_3), 18.90 (–, CH_3); MS (80 °C, 70 eV): *m z* (%): 513 (2) [M^+ +1], 512 (4) [M^+], 371, 351, 225, 105 (100), 101, 95, 83, 79. Data for (*R*)**G2b**: yield 42%, colourless crystals, m.p. 87 °C, $[\alpha]_D^{20}$ = 15.0° (*c* = 1.45 in CH_2Cl_2); IR ($CHCl_3$): ν = 3308 cm^{-1}, 2988, 2936, 1720, 1600, 1224, 1092, 944; ^1H NMR ($CDCl_3$): δ = 8.15 - 8.04 (m, 2H; arom. H), 7.65 - 7.41 (m, 3H; arom. H), 5.42 (d, *J* = 5 Hz, 1H; H-9a), 5.41 (dd, *J* = 9, 10 Hz, 1H; H-4), 3.97 (ddd, *J* = 4, 6, 9 Hz, 1H; H-8), 3.97 - 3.74 (m, 2H; H-8, H-8a), 3.86 (dd, *J* = 9, 9 Hz, 1H; H-4a), 3.72 (dt, *J* = 5, 10 Hz, 1H; H-2), 3.25 (dd, *J* = 6, 10 Hz, 1H; H-4′), 3.12 (dd, *J* = 8, 10 Hz, 1H; H-4′), 2.72 (dd, *J* = 3, 5 Hz, 1H; H-3′), 2.66 (dddd, *J* = 2, 6, 8, 10 Hz, 1H; H-3), 2.33 (ddd, *J* = 2, 5, 10 Hz, 1H; H-3a), 2.16 (t, *J* = 3 Hz, 1H; H-1′), 1.47 (s, 3H; CH_3), 1.33 (s, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 166.19 (+, C=O), 133.12 (–, arom. C), 129.87 (–, arom. C), 128.36 (–, arom. C), 99.99 (–, C-9a), 99.67 (+, C-6), 79.55 (+, C-2′), 78.62 (–, C-2), 73.41 (–, C-4), 71.27 (–, C-4a), 71.24 (+, C-1′), 65.27 (–, C-8a), 61.99 (+, C-8), 49.68 (–, C-3), 48.44 (–, C-3a), 28.90 (–, CH_3), 24.65 (+, C-3′), 18.96 (–, CH_3), 9.14 (+, C-4′); MS (110 °C, 70 eV): *m z* (%): 512 (0.5) [M^+], 497, 371, 225, 105, 101, 95, 92, 91, 87, 85, 83 (100).

6-Iodo-4(R)-trimethylsilyl-2,3,3a,3b,7,7a(R),8a-octahydro-1,8-dioxacyclopent[a]indene (*R,E*)**2a**. Precursor (*R,E*)**2** (300 mg, 0.82 mmol) was allowed to react according to method A (optimized) to afford after chromatography (MTBE/PE, 1 : 9) (*R,E*)**2a** (222 mg, 74%) as colourless crystals, m.p. 129 - 131°C. IR ($CHCl_3$): ν = 3027 cm^{-1}, 2948, 1603, 1251, 1001, 869; ^1H NMR ($CDCl_3$): δ = 6.18 - 6.15 (m, 1H; H-5), 5.68 (d, *J* = 5.5 Hz, 1H; H-8a), 4.01 (bt, *J* = 8 Hz, 1H; H-2), 3.93 - 3.76 (m, 1H; H-2), 3.49 (dt, *J* = 5.5, 10 Hz, 1H; H-7a), 2.70 (dddd, *J* = 2.5, 5.5, 10, 18 Hz, 1H; H-7), 2.70 (ddd, *J* = 2.5, 4.5, 10, 18 Hz, 1H; H-7), 2.45 (dt, *J* = 5.5, 8 Hz, 1H; H-3a), 2.07 - 1.85 (m, 1H; H-3), 1.78 - 1.56 (m, 2H; H-3, H-4), 1.37 (q, *J* = 10 Hz, 1H; H-3b), 0.10 (s, 9H; $SiMe_3$); ^{13}C NMR ($CDCl_3$): δ = 138.32 (–, C-5), 108.98 (–, C-8a), 90.74 (+, C-6), 79.42 (–, C-7a), 66.65 (+, C-2), 47.33 (–, C-3b), 46.28 (–, C-3a), 45.45 (+, C-7), 37.03 (–, C-4), 32.69 (+, C-3), −2.32 (–, $SiMe_3$); MS (70 eV): *m/z* (%): 364 (2) [M^+], 237 (60), 219 (11), 167 (60), 147 (25), 91 (100).

6-Iodo-4(S)-trimethylsilyl-2,3,3a,3b,7,7a(S),8a-octahydro-1,8-dioxacyclopent[a]indene (*S,E*)**2a**. Precursor (*S,E*)**2** (500 mg, 1.37 mmol) was allowed to react according to method B to afford after chromatography (MTBE/PE, 1 : 9) (*S,E*)**2a** (244 mg, 49%) as colourless crystals, m.p. 109 °C. IR (KBr): ν = 2955 cm^{-1}, 2906, 1250, 1108, 1093, 965, 948; ^1H NMR ($CDCl_3$): δ = 6.25 - 6.19 (m, 1H; H-5), 5.75 (d, *J* = 5 Hz, 1H; H-8a),

4.00 - 3.72 (m, 3H; H-2, H-7a), 2.95 (dddd, *J* = 1, 2, 6.5, 17 Hz, 1H; H-7), 2.88 - 2.78 (m, 1H; H-3a), 2.60 - 2.42 (m, 1H; H-7), 1.94 - 1.66 (m, 4H; H-3, H-3b, H-4), 0.08 (s, 9H; $SiMe_3$); ^{13}C NMR ($CDCl_3$): δ = 138.07 (–, C-5), 109.23 (–, C-8a), 88.96 (+, C-6), 78.35 (–, C-7a), 68.96 (+, C-2), 45.63 (+, C-7), 45.06 (–, C-3a), 43.87 (–, C-3b), 32.67 (–, C-4), 25.09 (+, C-3), –2.65 (–, $SiMe_3$); MS (70 eV): *m/z* (%): 364 (2) [M^+], 237 (42), 219 (26), 147 (20), 119 (40), 91 (100).

*6-Iodo-4(*R*)-methyl-2,3,3a,3b,7,7a(*R*),8a-octahydro-1,8-dioxacyclopent[a]indene* (*R,E*)**3a**, *6-Iodo-4(*S*)-methyl-2,3,3a,3b,7,7a(*R*),8a-octahydro-1,8-dioxacyclopent[a]indene* (*R,E*)**3b** *and 5-Iodomethylene-4(*S*)-methyl-octahydrocyclopent[a]pentalene* (*R,E*)**3c**. Precursor (*R,E*)**3** (1.5 mmol) was allowed to react according to method C to afford (*R,E*)**3a**, (*R,E*)**3b**, (*R,E*)**3c**. Data for (*R,E*)**3a** (51%), colourless oil. IR (film): ν = 2958 cm^{-1}, 1613, 1067, 981, 941; ^1H NMR ($CDCl_3$): δ = 6.15 (m, 1H; H-5), 5.69 (d, *J* = 6 Hz, 1H; H-8a), 4.02 (dd, *J* = 8, 16 Hz, 1H; H-2), 3.84 (ddd, *J* = 5, 8, 16 Hz, 1H; H-2), 3.53 (ddd, *J* = 6, 10, 10 Hz, 1H; H-7a), 2.94 (dddd, *J* = 1, 2, 6, 16 Hz, 1H; H-7), 2.68 (m, 1H; H-7), 2.51 (ddd, *J* = 6, 8, 9 Hz, 1H; H-3a), 2.26 (m, 1H; H-4), 1.94 (ddd, *J* = 8, 8, 12 Hz, 1H; H-3), 1.72 (dd, *J* = 5, 12 Hz, 1H; H-3), 1.11 (m, 4H; H-3b, CH_3); ^{13}C NMR ($CDCl_3$): δ = 143.58 (–, C-5), 109.14 (–, C-8a), 91.34 (+, C-6), 78.03 (–, C-7a), 66.86 (+, C-2), 51.08 (–, C-4), 47.03 (–, C-3a), 45.32 (+, C-7), 39.33 (–, C-3b), 31.85 (+, C-3), 19.09 (–, CH_3); MS (70 eV): *m/z* (%): 307 (4) [M^+ + 1], 306 (32) [M^+], 139, 133, 105, 92, 91 (100), 83, 79, 77. Data for (*R,E*)**3b** (7%), light-yellow solid, m.p. 139 °C. IR (KBr): ν = 2960 cm^{-1}, 1613, 1058, 983, 931; ^1H NMR ($CDCl_3$): δ = 6.37 (ddd, *J* = 1, 3, 4 Hz, 1H; H-5), 5.66 (d, *J* = 6 Hz, 1H; H-8a), 4.02 (dd, *J* = 8, 8 Hz, 1H; H-2), 3.86 (ddd, *J* = 5, 7, 12 Hz, 1H; H-2), 3.67 (ddd, *J* = 5, 10, 12 Hz, 1H; H-7a), 2.96 (ddd, *J* = 1, 5, 17 Hz, 1H; H-7), 2.78 - 2.50 (m, 3H; H-3a, H-4, H-7), 1.91 (m, 1H; H-3), 1.60 (dd, *J* = 6, 10 Hz, 1H; H-3), 1.68 (ddm, *J* = 5, 12 Hz, 1H; H-3b), 1.07 (d, *J* = 9 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 143.14 (–, C-5), 108.96 (–, C-8a), 91.68 (+, C-6), 73.96 (–, C-7a), 66.86 (+, C-2), 46.76 (–, C-3a), 46.27 (+, C-7), 43.39 (–, C-4), 35.02 (–, C-3b), 30.47 (+, C-3), 18.95 (–, CH_3); MS (70 eV): *m/z* (%): 307 (14) [M^+ + 1], 306 (100) [M^+], 197, 139, 133, 105, 91, 84, 83. Data for (*R,E*)**3c** (4%), yellow oil. IR (film): ν = 2964 cm^{-1}, 2252, 1600, 1048, 948, 924; ^1H NMR ($CDCl_3$): δ = 5.92 (d, *J* = 2 Hz, 1H; H-6), 5.62 (d, *J* = 5 Hz, 1H; H-8a), 4.65 (dt, *J* = 4, 16 Hz, 1H; H-7a), 3.92 (m, 1H; H-2), 3.80 (q, *J* = 8 Hz, 1H; H-2), 2.94 (m, 1H; H-3a), 2.73 (bq, *J* = 7 Hz, 1H; H-4), 2.64 (dd, *J* = 2, 4 Hz, 1H; H-7), 2.52 (ddd, *J* = 2, 6, 9 Hz, 1H; H-3b), 1.87 (m, 2H; H-3), 1.10 (d, *J* = 7 Hz, CH_3); ^{13}C NMR ($CDCl_3$): δ = 157.49 (+, C-5), 110.68 (–, C-8a), 84.08 (–, C-7a), 70.02 (–, C-6), 68.85 (+, C-2), 52.23 (–, C-4), 46.48 (–, C-3b), 43.41 (–, C-3a), 39.62 (+, C-7), 27.53 (+, C-3), 20.25 (–, CH_3); MS (70 eV): *m/z* (%): 306 (2) [M^+], 219 (100), 218, 133, 105, 93, 92, 91, 83, 79.

*6-Iodo-4(*S*)-methyl-2,3,3a,3b,7,7a(*S*),8a-octahydro-1,8-dioxacyclopent[a]indene* (*S,E*)**3a**. Precursor (*S,E*)**3** (1.4 mmol) was allowed to react according to method C to afford (*S,E*)**3** (70%) as light-yellow oil. IR (film): ν = 2957 cm^{-1}, 1614, 1102, 1032, 972, 937; ^1H NMR ($CDCl_3$): δ = 6.19 (bs, 1H; H-5), 5.78 (d, *J* = 5 Hz, 1H; H-8a), 3.90 (m, 2H; H-2), 3.81 (ddd, *J* = 6, 10, 11 Hz, 1H; H-7a), 2.94 (ddm, *J* = 6, 16 Hz, 1H; H-7), 2.93 (dddd, *J* = 4, 6, 8, 10 Hz, 1H; H-3a), 2.53 (dm, *J* = 16 Hz, 1H; H-7), 2.30 (m, 1H; H-4), 1.88 (m, 1H; H-3), 1.77 (m, 1H; H-3), 1.07 (d, *J* = 9 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 143.24 (–, C-5), 109.48 (–, C-8a), 91.44 (+, C-6), 77.36 (–, C-7a), 69.21 (+, C-2), 50.29 (–, C-4), 45.88 (+, C-7), 43.33 (–, C-3a), 35.93 (–, C-3b), 25.40 (+, C-3), 18.95 (–, CH_3); MS (70 eV): *m/z* (%): 307 (10) [M^+ + 1], 306 (83) [M^+], 179, 161, 149, 139, 133 (100), 107, 105, 93, 92, 91, 83.

*6-Iodo-4(*R,S*)-deutero-2,3,3a,3b,7,7a(*R*),8a-octahydro-1,8-dioxacyclopent[a]indene* (*R,E*)**4a**. Precursor (*R,E*)**4** (1.0 mmol) was allowed to react according to method C to afford (*R,E*)**4a** (42%) as yellowish solid, m.p. 91 °C. IR (KBr): ν = 2974 cm^{-1}, 1613, 1107, 1044, 973; ^{1}H NMR ($CDCl_3$): δ = 6.33 (m, 1H; H-5), 5.70 (d, *J* = 6 Hz, 1H; H-8a), 4.03 (t, *J* = 8 Hz, 1H; H-2), 3.86 (ddd, *J* = 5, 8, 12 Hz, 1H; H-2), 3.52 (ddd, *J* = 6, 10, 10 Hz, 1H; H-7a), 2.97 (dddd, *J* = 2, 3, 5, 17 Hz, 1H; H-7), 2.72 (ddm, *J* = 10, 17 Hz, 1H; H-7), 2.49 (ddd, *J* = 6, 8, 10 Hz, 1H; H-3a), 2.02 (m, 0.5H; H-4), 1.90 (dddd, *J* = 4, 8, 12, 12 Hz, 1H; H-3), 1.72 (dd, *J* = 5, 12 Hz, 1H; H-3), 1.51 (bq, *J* = 10 Hz, 1H; H-3b), 1.39 (m, 0.5H; H-4); ^{13}C NMR ($CDCl_3$): δ = 136.76 (–, C-5), 109.02 (–, C-8a), 92.37 (–, C-6), 78.36 (–, C-7a), 66.85 (+, C-2), 47.68/47.65 (–, C-3a), 45.45 (+, C-7), 42.28 (–, C-3b), 32.92/32.47/32.10 (–, C-4), 30.56 (+, C-3); MS (70 eV): *m z* (%): 294 (4) [M$^+$ + 1], 293 (25) [M$^+$], 166, 120, 119, 93, 92 (100), 91, 83.

*6-Iodo-4(*R,S*)-deutero-2,3,3a,3b,7,7a(*S*),8a-octahydro-1,8-dioxacyclopent[a]indene* (*S,E*)**4a**. Precursor (*S,E*)**4** (1.7 mmol) was allowed to react according to method C to afford (*S,E*)**4a** (38%) as yellowish solid, m.p. 111 °C. IR (KBr): ν = 2979 cm^{-1}, 1610, 1106, 1024, 956; ^{1}H NMR ($CDCl_3$): δ = 6.34 (m, 1H; H-5), 5.78 (d, *J* = 5 Hz, 1H; H-8a), 3.91 (m, 2H; H-2), 3.78 (ddd, *J* = 5, 10, 11 Hz, 1H; H-7a), 3.00 (ddd, *J* = 1, 5, 16 Hz, 1H; H-7), 2.55 (ddm, *J* = 10, 16 Hz, 1H; H-7), 2.87 (ddt, *J* = 5, 7, 10 Hz, 1H; H-3a), 2.28/2.06 (m, 1H; H-4), 2.00 - 1.67 (m, 3H; H-3, H-3b); ^{13}C NMR ($CDCl_3$): δ = 136.78 (–, C-5), 109.44 (–, C-8a), 91.88 (–, C-6), 77.53 (–, C-7a), 69.18 (+, C-2), 45.98 (+, C-7), 44.50 (–, C-3a), 42.32 (–, C-3b), 30.02/29.61/29.23 (–, C-4), 24.80 (+, C-3); MS (70 eV): *m z* (%): 294 (12) [M$^+$ + 1], 293 (94) [M$^+$], 166, 148, 120, 119, 94, 93, 92 (100), 91, 83.

*2(*R*),3(*S*),4(*R*),4a(*R*),4b(*R*),5(*R*),8a(*S*),9a(*S*)-2-Acetoxymethyl-7-iodo-5-methyl-3,4,4a,4b,5,8,8a,9a-octahydro-2*H*-pyrano[2,3-b]benzofuran-3,4-diol Diacetate* (*S*)**G4a**. Precursor (*S*)**G4** (0.9 mmol) was allowed to react according to method C to give (*S*)**G4a** (37%) as colourless crystals, m.p. 169 °C, $[\alpha]_D^{20}$ = 116.6° (*c* = 1.2 in CH_2Cl_2). IR (KBr): ν = 2936 cm^{-1}, 1747, 1244, 1045; ^{1}H NMR ($CDCl_3$): δ = 6.13 (bs, 1H; H-6), 5.62 (d, *J* = 4 Hz, 1H; H-9a), 5.18 (dd, *J* = 9, 10 Hz, 1H; H-3), 5.02 (dd, *J* = 9, 10 Hz, 1H; H-4), 4.44 (dd, *J* = 4, 12 Hz, 1H; H-10), 4.20 (ddd, *J* = 5, 10, 11 Hz, 1H; H-8a), 4.07 (dd, *J* = 2, 12 Hz, 1H; H-10), 4.02 (ddd, *J* = 2, 4, 10 Hz, 1H; H-2), 3.02 (dd, *J* = 5, 16 Hz, 1H; H-8), 2.58 (m, 3H; H-4a, H-8), 2.22 (m, 1H; H-5), 2.08 (s, 3H; CO_2CH_3), 2.03 (s, 3H; CO_2CH_3), 2.02 (s, 3H; CO_2CH_3), 1.77 (dt, *J* = 5, 11 Hz, 1H; H-4b), 1.00 (d, *J* = 6 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 170.63 (+, C=O), 169.98 (+, C=O), 169.94 (+, C=O), 143.09 (–, C-6), 102.24 (–, C-9a), 90.35 (+, C-7), 77.44 (–, C-8a), 69.52 (–, C-2), 68.94 (–, C-3), 68.43 (–, C-4), 61.83 (+, C-10), 49.32 (–, C-4a), 46.00 (+, C-8), 42.47 (–, C-4b), 34.66 (–, C-5), 20.73 (–, $COCH_3$), 20.65 (–, $COCH_3$), 20.65 (–, $COCH_3$), 18.66 (–, CH_3); MS (70 eV): *m z* (%): 508 (1) [M$^+$], 236, 213, 153, 111, 109 (100), 92, 01, 79.

*2(*R*),3(*S*),4(*R*),4a(*R*),4b(*S*),5(*R*),8a(*R*),9a(*S*)-2-Acetoxymethyl-7-iodo-5-methyl-3,4,4a,4b,5,8,8a,9a-octahydro-2*H*-pyrano[2,3-b]benzofuran-3,4-diol Diacetate* (*R*)**G4a**. Precursor (*S*)**G4** (0.86 mmol) was allowed to react according to method C to give (*R*)**G4a** (19%) as light-yellow, glassy oil, $[\alpha]_D^{20}$ = –29.0° (*c* = 3.3 in CH_2Cl_2). IR ($CHCl_3$): ν = 3040 cm^{-1}, 2964, 1740, 1236, 1032, 980; ^{1}H NMR ($CDCl_3$): δ = 6.13 (bs, 1H; H-6), 5.56 (d, *J* = 4 Hz, 1H; H-9a), 5.13 (m, 1H; H-4), 4.95 (d, *J* = 9 Hz, 1H; H-3), 4.22 (d, *J* = 5 Hz, 2H; H-10), 3.59 (ddd, *J* = 6, 11, 11 Hz, 1H; H-8a), 3.98 (dd, *J* = 5, 9 Hz, 1H; H-2), 3.01 (ddd, *J* = 3, 6, 17 Hz, 1H; H-8), 2.66 (m, 1H; H-8), 2.12 (m, 1H; H-5), 2.36 (m, 1H; H-4a), 2.11 (s, 9H; CO_2CH_3), 1.63 (q, *J* = 11 Hz, 1H; H-4b), 1.18 (d, *J* = 6 Hz, 3H; CH_3); ^{13}C NMR ($CDCl_3$): δ = 170.60 (+, C=O), 169.60 (+, C=O), 169.13 (+, C=O),

143.09 (–, C-6), 99.51 (–, C-9a), 91.23 (+, C-7), 78.04 (–, C-8a), 70.63 (–, C-2), 68.87 (–, C-3), 66.78 (–, C-4), 63.71 (+, C-10), 46.93 (–, C-4a), 45.13 (+, C-8), 44.31 (–, C-4b), 40.17 (–, C-5), 20.95 (–, $COCH_3$), 20.74 (–, $COCH_3$), 20.72 (–, $COCH_3$), 19.65 (–, CH_3); FAB-MS (70 eV): *m/z* : 509 [M^+ + 1]

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