CHAPTER-II

SECTION-B

Radical mediated synthesis of cis-fused bicyclic systems from L-arabinose and D-xylose
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Section B deals with radical mediated synthesis of cis-fused bicyclic systems from L-arabinose and D-xylose

The nature has its creation by diversity oriented synthesis (DOS), whereby nature designs molecules of skeletal, structural, stereochemical and functional diversity. For eg: macrosphelides, a macrotriolide class of natural products, which differ in the stereochemistry and arrangement of the functional groups. Yet another example of nature’s DOS is reflected by the presence of a variety of α-methylene bis-butyrolactones. This class of natural products differs in the length of their side chains and the arrangement of the bicyclic systems to result in diversely fused furo-furan systems.

Earlier, we have extensively worked on the synthesis of this class of natural products such as xylobovide $^{17}$, canadensolide $^{18}$, sporothriolide $^{19}$, epithisolide $^{20}$, avenaciolide $^{21}$, discocilide $^{22}$ (Figure 2) and others by the adoption of 5-exo-dig$^7$ radical route to introduce both cis-fused bicyclic systems besides the simultaneous introduction of efficient introduction of exo-methylene group.

Further studies revealed that all types of bis-butyro-lactones could not be prepared by radical cyclization approach. It was found from our studies that the side chain in a specific stereochemistry has an impact on the cyclization by radical route. However, to encounter such situations, yet another protocol was adopted, where, the inversion of centre takes place during radical cyclization. Hence, to encounter such situations and to create diversity of side chains and functionalized side chains, it was proposed to first build different types of cis-fused bicyclic systems, which on further transformations could create further diversity.

As was discussed in the Chapter I, the side chain effect was amply evident in furanoside systems with L-Ara configuration, rather than in systems with D-Xylo configuration. The synthesis of iso-avenaciolide $^{4}$ by 5-exo-dig mode was not possible in our hands probably due to side chain effect. In addition, nature has a diversity of bis-butyro-lactone containing natural products such as, ethisolide $^{3}$ and iso-avenaciolide $^{4}$ along with non-natural products such as, iso-canadensolide $^{1}$ and iso-sporothriolide $^{2}$ (Figure 1). Hence, in this study it was proposed to undertake the synthesis of cis-fused bicyclic systems by 5-exo-dig radical cyclization$^{11}$ from the precursors with L-Ara and D-Xylo configurations, so that requisite side chain or other diversity
can be introduced accordingly on these bicyclic systems. Since, the problems were encountered with L-Ara configuration, the work was initiated on the synthesis of bicyclic systems 5 and 6 from L-Ara.

Figure 1

![Figure 1](image)

According to the retrosynthetic strategy, the bicyclic systems 5 and 6 could be made from the radical precursors 7 and 8, while, the xanthate derivatives 7 and 8 in turn could be realized from the known L-arabinose derivative 9 (Scheme 1).

Scheme 1

Accordingly, known alcohol 9 (Scheme 2) was subjected to alkylation with propargyl bromide in the presence of NaH in THF at room temperature for 4 h to furnish the required 2-O-propargyl ether 10 in 91% yield. In the $^1$H NMR spectrum of 10, propargylic protons resonated at $\delta$ 2.42 as a broad singlet corresponding to acetylenic proton, whereas rest of the protons resonated at the appropriate chemical shifts. HRMS showed $m/z$ 489.20490 for $C_{27}H_{34}O_5NaSi (M+Na)^+$ confirming the structure of 10.
Methanolysis of 10 with methanol containing conc. HCl (cat.) at 0 °C to room temperature for 6 h gave the diastereomeric mixture of α- and β-methyl glycosides 11 with concomitant hydrolysis of TBDPS group.

Hence, the anomeric mixture 11 was subjected to reaction with TBDPSCI and imidazole in dry CH₂Cl₂ at 0 °C to room temperature for 2 h to give the mixture of 12 and 12a (Scheme 3). Purification of the mixture by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) gave the α-anomer 12 (33%) and β-anomer 12a (49%).

In the ¹H NMR spectrum of α-anomer 12, H-2 resonated at δ 4.82 (J = 4.7 Hz) as a doublet and -OMe appears at δ 3.37 as a singlet, while in β-anomer 12a H-2 appeared at δ 4.94 as a singlet and -OMe appears at δ 3.41 as a singlet, while rest of the protons resonated at the appropriate chemical shifts. HRMS showed m/z 463.19078 and 463.19095 for C₂₅H₃₂O₅NaSi (M+Na)⁺ confirming the structures of 12 and 12a.

The β-anomer 12a on reaction with NaH, CS₂ and MeI in THF at 0 °C to room temperature for 2 h furnished the xanthate ester 7 in 90% yield (Scheme 4). In ¹H NMR spectrum of 7 the methylthio group resonated at δ 2.54 as a singlet, while the H-3 proton shifted to downfield and appeared at δ 5.85 as a singlet. HRMS showed m/z 531.16895 for C₂₇H₅₅O₅S₂Si (M+Na)⁺ confirming the structure of 7.
Radical cyclization of 7 under standard reaction conditions using $n$-Bu₃SnH and AIBN (cat.) in dry benzene at reflux for 12 h afforded 5 in 69% yield (Scheme 5). In $^1$H NMR spectrum of 5, it showed the disappearance of the methylthio ester signals at $\delta$ 2.54. The H-4 proton resonated at $\delta$ 5.12 ($J = 6.0$ Hz) as a doublet, while the exo-cyclic double bond protons resonated at $\delta$ 5.05 as a broad singlet. HRMS showed $m/z$ 447.19692 for C$_{25}$H$_{32}$O$_4$NaSi (M+Na)$^+$ confirming the structure of 5. The optical rotation value for 5 in chloroform was $[\alpha]_D = -45.7$ (c 0.1).

Having successfully synthesized the cis-fused bicyclic furo-furan system 5, the study was then extended to the synthesis of the other furo-furan namely 6 by the use of radical generated at C-3. Accordingly, known PMB ether 13 on methanolysis in MeOH with conc. HCl at room temperature for 6 h gave the glycoside mixture 14, which on reaction with TBDPSCl and imidazole in CH$_2$Cl$_2$ at 0 °C to room temperature for 2 h gave the silyl ethers 14a (Scheme 6).

Alkylation reaction of 14a with propargyl bromide in the presence of NaH in THF at room temperature for 4 h afforded the ethers 15 (34%) and 15a (50%) (Scheme 7) after column
chromatography purification. In the $^1$H NMR spectrum of $\alpha$-anomer 15, H-5 resonated at $\delta$ 4.53 ($J = 4.4$ Hz) as a doublet, while H-3 and H-4 at $\delta$ 3.93 ($J = 5.9$, 11.4 Hz) as a quintet and $\delta$ 4.27 as a multiplet. The PMB signals at $\delta$ 6.81 and $\delta$ 7.12 ($J = 8.4$ Hz) as two doublets, while propargylic proton resonated at $\delta$ 2.19 as a broad singlet. In the $^1$H NMR spectrum of $\beta$-anomer 15a, H-5 appeared at $\delta$ 4.74 as a singlet, while H-3 and H-4 at $\delta$ 3.94 ($J = 3.4$ Hz) as a doublet and $\delta$ 4.27 as a singlet. The PMB signals at $\delta$ 6.76 and $\delta$ 7.03 ($J = 8.4$ Hz) as two doublets, while propargylic proton resonated at $\delta$ 2.20 as a broad singlet, while rest of the protons resonated at the appropriate chemical shifts.

Scheme 7

![Scheme 7]

To create the radical precursor, 15a was subjected to oxidative deprotection of PMB group with DDQ in aq. CH$_2$Cl$_2$ at room temperature for 2 h to give the alcohol 16 in 75% yield (Scheme 8). In $^1$H NMR spectrum of 16, the aromatic protons disappeared, while rest of the protons resonated at the expected chemical shifts.

Scheme 8

![Scheme 8]

Thus, the derived alcohol 16 on reaction with NaH and CS$_2$ followed by MeI was converted into the xanthate ester 8 in 85% yield (Scheme 8). In $^1$H NMR spectrum of 8 the methylthio group resonated at $\delta$ 2.44 as a singlet, while the H-3 proton shifted to downfield and appeared at $\delta$ 6.04 ($J = 1.32$, 3.39 Hz) as a doublet of doublet. Rest of the protons resonated at the appropriate chemical shifts. HRMS showed $m/z$ 531.16889 for C$_{27}$H$_{35}$O$_5$S$_2$Si (M+Na)$^+$ confirming the structure of 8. The optical rotation value for 8 in chloroform are $[\alpha]_D = -87.5$ (c 0.32).
The xanthate ester 8 was subjected to radical cyclization reaction with \( n\)-Bu\(_3\)SnH and AIBN (cat.) in dry benzene at reflux for 12 h. However, the reaction met with failure to give the expected cyclic system 6 (Scheme 9), unlike in the case of 7 giving 5. These findings become now very interesting, since, the resistance of the C-3 radical to undergo radical cyclization is attributable to the L-Ara configuration or to the bulkyness of the protecting group (-CH\(_2\)OTBDPS).

Scheme 9

![Scheme 9]

To understand the above discussed results and develop the other cis-fused bicyclic systems with different stereocentres, the study was extended to the synthesis of bicyclic systems having D-Xylo configuration. This study further acquires importance, since several natural products, as shown in Figure 2 have two different kinds of furo-furan moieties\(^{1-6}\) (17-22) with D-Xylo configuration.

Figure 2

![Figure 2]

The similar retrosynthetic strategy that was used for the synthesis of bicyclic systems from L-Ara was adopted for the synthesis of bicyclic systems 23 and 24. Thus, 23 and 24 could be made from the xanthates 25 and 26, which inturn could be realized from D-xylose derivative 27 (Scheme 10).
Accordingly, the known diol 27 was treated with TBDPSCI in presence of imidazole in CH₂Cl₂ at 0 °C to room temperature for 2 h to afford silyl ether 28 in 70% yield (Scheme 11). In the ¹H NMR spectrum of 28, H-3a and H-6a protons resonated at δ 6.0 and 4.54 (J = 3.5 Hz) as two doublets, while acetonide protons showed at δ 1.33 and 1.46 as two singlets. The TBDPS protons at δ 1.05 as singlet corresponding to tert.butyl proton and aromatic protons resonated at δ 7.41 and 7.69 as two multiplets. HRMS showed m/z 451.1895 for C₂₄H₃₂O₅NaSi (M+Na)⁺ confirming the structure of 28.

Alcohol 28 was subjected to alkylation with propargyl bromide in the presence of NaH in THF at room temperature for 4 h to furnish 29 in 80% yield (Scheme 12). In the ¹H NMR spectrum of 29, propargylic protons resonated at δ 2.42 (J = 2.3 Hz) as a triplet corresponding to acetylenic proton, while, rest of the protons resonated at the appropriate chemical shifts. HRMS showed m/z 489.20490 for C₂₇H₃₄O₅NaSi (M+Na)⁺ confirming the structure of 29.
Chapter II, Section-B, Present work

Hydrolysis of acetonide 29 on reaction with methanol containing conc. HCl (cat.) at 0 °C to room temperature for 6 h gave the α- and β-methyl glycoside mixture 30 with concomitant hydrolysis of TBDPS group (Scheme 13).

The anomeric mixture 30 on reaction with TBDPSCl and imidazole in CH₂Cl₂ at 0 °C to room temperature for 2 h furnished β-anomer as a major anomer 31 (44%) after column chromatography purification (Scheme 14). In the ¹H NMR spectrum of β-anomer 31 H-2 proton appeared at δ 4.69 as a singlet and H-3 appeared at δ 4.57 as a multiplet, while anomeric OCH₃ showed at δ 3.19 as a singlet. Rest of the protons resonated at the appropriate chemical shifts. HRMS showed m/z 463.19078 for C₂₅H₃₂O₅NaSi (M+Na)⁺ confirming the structure of 31.

The β-anomer 31 on reaction with NaH, CS₂ and MeI in THF at 0 °C to room temperature for 2 h furnished the xanthate ester 25 in 70% yield (Scheme 15). In ¹H NMR spectrum of 25 the methylthio group resonated at δ 2.46 as a singlet, while the H-2 proton resonated at δ 4.69 as a singlet and the H-3 proton at δ 5.99 (J = 5.0 Hz) as a doublet. HRMS showed m/z 531.16949 for C₂₇H₃₅O₅S₂Si (M+Na)⁺ confirming the structure of 25. The optical rotation value for 25 in chloroform was [α]D = -20.46 (c 0.17).
Chapter II, Section-B, Present work

Radical cyclization of 25 on reaction with n-Bu3SnH in the presence AIBN (cat.) in dry benzene at reflux for 12 h afforded 23 in 71% yield (Scheme 16). In 1H NMR spectrum of 23, the exo-cyclic double bond protons resonated at $\delta$ 5.02 as broad singlet, while H-4, H-6a and H-3a at $\delta$ 4.96 ($J = 6.0$ Hz) as a doublet and $\delta$ 4.65 as a multiplet. The rest of the protons resonated at the appropriate chemical shifts. HRMS showed $m/z$ 447.19538 for C25H32O4Si (M+Na)$^+$ confirming the structure of 23. The optical rotation value for 23 in chloroform was $[\alpha]_D = -32.7$ (c 0.31).

Having successfully synthesized the bicyclic systems using C-2 radical, the study was then extended to the C-3 radical mediated formation of bicyclic system. Accordingly, the known silyl ether 28 on reaction with PMBBr in the presence of NaH in dry THF at 0 °C to room temperature for 4 h furnished 32 in 83% yield (Scheme 17). In 1H NMR spectrum of 32, the newly introduced PMB protons resonated at $\delta$ 3.79 as a singlet for Ar-OCH3 and at $\delta$ 6.82 and $\delta$ 7.22 ($J = 8.6$ Hz) as two doublets for aromatic group, while rest of the protons at the expected chemical shifts. HRMS showed $m/z$ 571.2512 for C32H40O6NaSi (M+Na)$^+$ confirming the structure of 32.
The PMB ether 32 on methanolyis (MeOH, conc. HCl) gave the glycosidic mixture 33, which on, further reaction with TBDPSCl and imidazole in CH₂Cl₂ at 0 °C to room temperature for 2 h gave 33a (Scheme 18).

**Scheme 18**

Alkylation of 33a with propargyl bromide in the presence of NaH in THF at room temperature for 4 h afforded the β-anomer as a major anomer 34a (53%) after chromatography purification (Scheme 19). In ¹H NMR spectrum of 34a, the H-5 proton resonated at δ 4.81 as a singlet, while H-4 and H-3 at δ 4.44 (J = 5.9, 10.9 Hz) as a quintet and δ 4.07 (J = 11.4 Hz) as a doublet. The PMB protons appeared at δ 6.70 and δ 6.90 (J = 7.9 Hz) as two doublets, while rest of the protons resonated at the expected chemical shifts.

**Scheme 19**

Oxidative deprotection of PMB group in 34a with DDQ in aq. CH₂Cl₂ at room temperature for 2 h to give the alcohol 35 in 76% yield (Scheme 20). In ¹H NMR spectrum of 35 showed the disappearance of PMB protons, while rest of the protons resonated at the expected chemical shifts. HRMS showed m/z 463.19086 for C₂₅H₃₂O₅NaSi (M+Na)^+ confirming the structure of 35.

**Scheme 20**

Reaction of alcohol 35 with NaH and CS₂ followed by alkylation with MeI, it was converted into the xanthate ester 26 in 81% yield (Scheme 21). In ¹H NMR spectrum of 26 the
methylthio group resonated at \( \delta 2.33 \) as a singlet and H-3 proton at \( \delta 6.06 \) (\( J = 1.5, 4.5 \) Hz) as doublet of doublet. The rest of the protons resonated at the appropriate chemical shifts.

**Scheme 21**

Finally, radical cyclization of 26 was carried out with \( n-\text{Bu}_3\text{SnH} \) and AIBN (cat.) in dry benzene at reflux for 12 h which however met with failure to give the expected cyclic system 24 (Scheme 22), unlike in the case of 25 giving 23. These findings become now very interesting, since, the resistance of the C-3 radical to undergo radical cyclization may be attributed to the bulkyness of the protecting group (-CH\(_2\)OTBDPS).

**Scheme 22**

Thus, the present study resulted in the formation of two *cis*-fused furo-furan bicyclic systems by the successful utilization of C-2 radical. These bicyclic systems, which look similar to canadensolide (18) class of natural products. Hence, synthesis of natural products and non-natural products structurally relevent to canadensolide (18) and others can be undertaken from these new bicyclic systems. Further studies on the utilization of C-3 radical cyclization of D-Xylo/L-Ara derived xanthates are in progress.
Experimental Section:

(3aR,5S,6S,6aR)-Tetrahydro-2,2-dimethyl-6-(prop-2-nyloxy)furo[2,3-d][1,3]dioxol-5-yl methoxy)(tert.-butyl)diphenylsilane (10): A stirred suspension of NaH (0.36 g, 14.95 mmol) in THF (6 mL) under N₂ atmosphere at 0 °C, was treated with a solution of alcohol 9 (3.20 g, 7.47 mmol) in THF (5 mL) and stirred for 15 min. Propargyl bromide (0.83 mL, 7.47 mmol) was added to the reaction mixture at 0 °C and stirred at room temperature for 4 h. Reaction mixture was quenched with aq. NH₄Cl solution (5 mL) and extracted with EtOAc (2 x 20 mL). Organic layer was washed with water (10 mL), brine (10 mL) and dried (Na₂SO₄). Solvent was evaporated and purified the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) afforded 10 (3.20 g, 91%) as a liquid; [α]D = -52.5 (c 4.1, CHCl₃); IR (neat): 3451, 3282, 2924, 1720, 1611, 1513, 1248, 1100, 1065, 1050, 943, 771 cm⁻¹; ¹H NMR (300 MHz, CDCl₃): 1.06 (s, 9H, C(CH₃)₃), 1.23-1.34 (m, 6H, 2xCH₃), 2.42 (s, 1H, acetylenic-H), 3.78-3.85 (m, 2H, OCH₂), 4.11-4.35 (m, 4H, H-5, H-6 and OCH₂), 4.62 (d, 1H, J = 3.2 Hz, H-6a), 5.85 (d, 1H, J = 3.2 Hz, H-3a), 7.35-7.44 (m, 6H, Ar-H), 7.66-7.71 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 135.5 (2C), 133.0 (2C), 129.6 (2C), 127.6 (4C), 112.3, 105.6, 84.9, 84.6, 82.1, 74.9, 63.1, 56.8, 26.7 (3C), 25.9 (2C), 19.1; HRMS (ESI): m/z calculated for C₂₇H₃₄O₅NaSi (M⁺+Na) 489.20677, found 489.20490.

(2S,3R,4R,5R)-5-((tert.-Butyldiphenylsilyl)methyl)-tetrahydro-2-methoxy-4-(prop-2-nyloxy)furan-3-ol (12) and (2R,3R,4R,5R)-5-((tert.-Butyldiphenylsilyl)methyl)-tetrahydro-2-methoxy-4-(prop-2-nyloxy)furan-3-ol (12a): To a solution of 10 (1.50 g, 6.57 mmol) in dry MeOH (20 mL) under N₂ atmosphere, 3 drops of conc. HCl was added at 0 °C and stirred for 6 h. The reaction mixture was cooled to 0 °C and neutralized with solid NaHCO₃ (0.5 g) at 0 °C. It was filtered, evaporated the solvent and purified the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.8:8.2) to afford anomeric mixture 11 (1.0 g, 75%) as a liquid, which was used as such for the next reaction.

To a stirred solution of anomeric mixture 11 (0.70 g, 3.46 mmol) in CH₂Cl₂ (10 mL), imidazole (0.47 g, 6.93 mmol) was added and the reaction mixture was stirred at 0 °C. After 10 min, TBDPSCl (0.95 g, 3.46 mmol) and DMAP (0.01 g) were added and stirred at room temperature for 2 h. The reaction mixture was diluted with CH₂Cl₂ (20 mL), washed with water (10 mL), brine (10 mL) and dried (Na₂SO₄). Solvent was evaporated and purified the residue by
column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.9:8.1) to afford α- and β-anomers in 1:1.5 ratio. First eluted was α-anomer 12 (0.50 g, 33%) as a syrup; [α]D = -1.07 (c 0.9, CHCl3); IR (neat): 3590, 3500, 2237, 1724, 1256, 867, 793 cm⁻¹; ¹H NMR (300 MHz, CDCl3): δ 1.07 (s, 9H, C(CH₃)₃), 2.40 (t, 1H, J = 2.4 Hz, acetylenic-H), 3.37 (s, 3H, OCH₃), 3.70-3.81 (m, 2H, OCH₂), 3.98 (q, 1H, J = 5.1, 10.5 Hz, H-5), 4.09 (t, 1H, J = 6.0 Hz, H-4), 4.17-4.22 (m, 1H, H-3), 4.32 (m, 2H, OCH₂), 4.82 (d, 1H, J = 4.7 Hz, H-2), 7.35-7.44 (m, 6H, Ar-H), 7.68-7.71 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 135.6 (2C), 129.6 (4C), 127.6 (2C), 102.2, 83.5, 81.8, 77.7, 74.5, 64.8, 57.3, 55.4, 26.7 (3C), 19.1; HRMS (ESI): m/z calculated for C₂₅H₃₂NaO₅Si (M⁺+Na) 463.19112, found 463.19078.

Second eluted was β-anomer 12a (0.75 g, 49%) as a syrup; [α]D = -41.9 (c 1.6, CHCl₃); IR (neat): 3590, 3500, 2237, 1724, 1256, 867, 793 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ 1.07 (s, 9H, C(CH₃)₃), 2.41 (t, 1H, J = 2.4 Hz, acetylenic-H), 3.41 (s, 3H, OCH₃), 3.77-3.89 (m, 3H, H-5 and OCH₂), 4.15-4.31 (m, 4H, H-3, H-4 and OCH₂), 4.94 (s, 1H, H-2), 7.35-7.44 (m, 6H, Ar-H), 7.68-7.71 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 135.6 (2C), 132.4 (2C), 129.9 (2C), 127.8 (4C), 109.8, 84.5, 84.0, 77.6, 74.9, 57.6, 55.1, 26.7 (3C), 19.1; HRMS (ESI): m/z calculated for C₂₅H₃₂NaO₅Si (M⁺+Na) 463.19112, found 463.19095.

O-(2R,3R,4R,5R)-5-((tert.-Butyldiphenylsilyl)methyl)-tetrahydro-2-methoxy-4-(prop-2-ynyloxy)furan-3-yl S-methyl carbonodithioate (7): A stirred suspension of NaH (0.08 g, 3.63 mmol) in dry THF (10 mL) under N₂ atmosphere was treated with a solution of 12a (0.80 g, 1.81 mmol) in THF (5 mL) at 0 °C and stirred at room temperature for 10 min. CS₂ (0.21 mL, 2.72 mmol) was added at 0 °C and stirred at room temperature for 10 min. MeI (0.17 mL, 2.72 mmol) was added at 0 °C and stirred at room temperature for 2 h. The reaction mixture was quenched with aq. NH₄Cl solution (5 mL) and extracted with EtOAc (3 x 10 mL). Organic layer was washed with water (10 mL), brine (10 mL) and dried (Na₂SO₄). Solvent was evaporated and purified the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1:9) to afford 7 (0.90 g, 90%) as light yellow liquid; [α]D = -35.6 (c 1.8, CHCl₃); IR (neat): 3453, 2867, 1742, 1489, 1224, 1057, 786 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): 1.10 (s, 9H, C(CH₃)₃), 2.39 (bs, 1H, acetylenic-H), 2.54 (s, 3H, S-CH₃), 3.41 (s, 3H, OCH₃), 3.90 (t, 2H, J = 4.2 Hz, OCH₂), 4.18 (q, 1H, J = 4.6, 8.9 Hz, H-5), 4.28 (s, 2H, OCH₂), 4.38 (d, 1H, J = 4.6 Hz, H-4), 5.04 (s, 1H, H-2), 5.85 (s, 1H, H-3), 7.35-7.44 (m, 6H, Ar-H), 7.66-7.71 (m, 4H, Ar-H); ¹³C
NMR (CDCl₃, 75 MHz): δ 214.6, 135.6 (2C), 133.3 (2C), 129.7 (2C), 127.6 (4C), 106.4, 89.1, 83.4, 82.2, 75.2, 62.9, 58.1, 54.8, 26.8 (3C), 19.3; HRMS (ESI): m/z calculated for C₂₇H₃₅O₅S₂Si (M+H)⁺ 531.16897, found 531.16895.

(((3aS,4R,6S,6aR)-Hexahydro-4-methoxy-3-methylenefuro[3,4-b]furan-6-yl)methoxy)(tert.-butyl)diphenylsilane (5): A solution of 7 (0.80 g, 1.45 mmol) in dry benzene (25 mL) under N₂ atmosphere was treated with n-Bu₃SnH (0.78 mL, 2.91 mmol) at room temperature and heated at reflux for 30 min. After 30 min, catalytic amount of AIBN was added at reflux and stirred for 12 h. The reaction mixture was cooled to room temperature, evaporated the solvent under reduced pressure and purified the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) to afford 5 (0.43 g, 69%) as a colorless liquid; [α]D = -45.7 (c 0.1, CHCl₃); IR (neat): 2864, 1756, 1612, 1387, 1234, 1113, 768 cm⁻¹; ¹H NMR (300 MHz, CDCl₃): δ 1.05 (s, 9H, C(CH₃)₃), 3.40 (s, 4H, H-3a and OCH₃), 3.77 (d, 2H, J = 3.3 Hz, OCH₂), 4.25-4.38 (m, 2H, OCH₂), 4.49-4.54 (m, 1H, H-6), 4.68 (dd, 1H, J = 2.2, 6.7, 9.0 Hz, H-6a), 5.05 (bs, 2H, olefinic), 5.12 (d, 1H, J = 6.0 Hz, H-4), 7.34-7.42 (m, 6H, Ar-H), 7.64-7.70 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 146.2, 135.5 (4C), 129.67 (2C), 127.6 (4C), 106.7, 105.9, 85.9, 84.1, 73.4, 64.5, 55.6, 54.9, 26.7, 19.2; HRMS (ESI): m/z calculated for C₂₅H₉₇O₅NaSi (M+Na)⁺ 447.19621, found 447.19692.

(((2S,3S,4R,5S)-3-(4-Methoxybenzylloxy)-tetrahydro-5-methoxy-4-(prop-2-ynyloxy)furan-2-yl)methoxy)(tert.-butyl)diphenylsilane (15) and (((2S,3S,4R,5R)-3-(4-methoxybenzylloxy)-tetrahydro-5-methoxy-4-(prop-2-ynyloxy)furan-2-yl)methoxy)(tert.-butyl)diphenylsilane (15a): To a solution of 13 (1.10 g, 3.54 mmol) in dry MeOH (15 mL) under N₂ atmosphere 2-3 drops of conc. HCl was added at 0 °C and stirred for 6 h. Work up as described for 11 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.8:8.2) afforded anomeric mixture 14 (0.36 g, 66%) as a liquid, which was used as such for the next reaction.

To a stirred solution of 14 (0.56 g, 1.97 mmol) in CH₂Cl₂ (5 mL), imidazole (0.26 g, 3.94 mmol) was added and the reaction mixture was stirred at 0 °C. After 10 min, TBDPSCI (0.51 mL, 1.97 mmol) and DMAP (0.01 g) were added and stirred at room temperature for 2 h. Work
up described for 12 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) afforded anomeric mixture 14a (0.74 g, 72%) as syrups.

A stirred suspension of NaH (0.08 g, 3.44 mmol) in dry THF (4 mL) under N₂ atmosphere was treated with a solution of anomeric mixture 14a (0.90 g, 1.72 mmol) in THF (4 mL) at 0 °C and stirred for 15 min. Propargyl bromide (0.25 mL, 1.72 mmol) was added to the reaction mixture at 0 °C and stirred for 4 h. Work up as described for 12 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 8.8:1.2) gave the α- and β-anomers. First eluted was α-anomer 15 (0.33 g, 34%) as a syrup; [α]₀ = -28.1 (c 0.81, CHCl₃); IR (neat): 3323, 3295, 2941, 1753, 1631, 1578, 1234, 1103, 1061, 955, 769 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ 1.06 (s, 9H, (CH₃)₃), 2.19 (bs, 1H, H-7), 3.06 (s, 3H, OCH₃), 3.66-3.74 (m, 2H, OCH₂), 3.78 (m, 4H, H-2 and Ar-OCH₃), 3.93 (q, 1H, J = 5.9, 11.4 Hz, H-3), 4.02 (d, 2H, J = 3.9 Hz, OCH₂), 4.12 (t, 2H, J = 6.9 Hz, OCH₂), 4.27 (m, 1H, H-4), 4.53 (d, 1H, J = 4.4 Hz, H-5), 6.81 (d, 2H, J = 8.4 Hz, Ar-H), 7.12 (d, 2H, J = 8.4 Hz, Ar-H), 7.29-7.41 (m, 6H, Ar-H), 7.66-7.72 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 159.0, 135.9 (2C), 135.8 (2C), 135.5 (2C), 130.3 (2C), 129.7, 129.6, 129.2, 127.6, 127.5, 113.6 (2C), 102.2, 84.3, 81.4, 78.8, 72.4, 66.3, 54.6, 26.9 (3C), 19.2.

Second eluted was β-anomer 15a (0.48 g, 50%) as a syrup; [α]₀ = -56.4 (c 0.7, CHCl₃); IR (neat): 3423, 3361, 2848, 1741, 1629, 1582, 1187, 1109, 1072, 955, 742 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ 1.07 (s, 9H, (CH₃)₃), 2.20 (s, 1H, H-7), 3.14 (s, 3H, OCH₃), 3.76-3.85 (m, 6H, H-2, OCH₂ and Ar-OCH₃), 3.94 (d, 1H, J = 3.4 Hz, H-3), 4.07-4.17 (m, 4H, 2xOCH₂), 4.27 (s, 1H, H-4), 4.74 (s, 1H, H-5), 6.76 (d, 2H, J = 8.4 Hz, Ar-H), 7.03 (d, 2H, J = 8.4 Hz, Ar-H), 7.32-7.42 (m, 6H, Ar-H), 7.62-7.72 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 159.0, 135.8 (2C), 135.6 (2C), 135.2 (2C), 134.7 (2C), 129.8, 129.6, 129.0, 127.6, 113.6 (2C), 109.6, 85.8, 84.1, 81.6, 77.2, 71.3, 64.6, 55.2, 26.8 (3C), 19.3.

(((2S,3S,4R,5R)-Tetrahydro-5-methoxy-4-(prop-2-ynyloxy)furan-2-yl)methoxy)(tert.-butyl)diphenylsilane-ol (16): To a stirred solution of 15a (0.10 g, 0.18 mmol) inaq. CH₂Cl₂ (1:19, H₂O:CH₂Cl₂, 10 mL) at 0 °C, DDQ (0.08 g, 0.36 mmol) was added and stirred at room temperature for 2 h. The reaction mixture was quenched with aq. NaHCO₃ solution (3 mL) and extracted with CH₂Cl₂ (2 × 10 mL). Organic layer was washed with aq. NaHCO₃ solution (5 mL), water (5 mL) and brine (5 mL). It was dried (Na₂SO₄), evaporated the solvent and purified
the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 4:1) to give 16 (0.06 g, 75%) as a syrup; [α]D = -32.4 (c 0.94, CHCl3); IR (neat): 3372, 2856, 1767, 1395, 1031, 792 cm⁻¹; ¹H NMR (300 MHz, CDCl3): δ 1.07 (s, 9H, -(CH₃)₃), 2.18 (d, 1H, J = 9.0 Hz, H-7), 3.17 (s, 3H, OCH₃), 3.80-3.90 (m, 3H, H-2 and OCH₂), 4.04-4.14 (m, 4H, OCH₂, H-3 and H-4), 4.70 (s, 1H, H-5), 7.35-7.44 (m, 6H, Ar-H), 7.60-7.72 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 135.5 (4C), 134.7 (2C), 129.6 (2C), 127.6 (2C), 109.0, 86.6, 82.0, 78.6, 64.6, 54.7, 26.8 (3C), 19.2; ESI-MS: m/z 440.

**O-(2S,3S,4R,5R)-Tetrahydro-2-(tert.-butyl-diphenylsilyloxyethyl)-5-methoxy-4-(prop-2-ynyloxy)furan-3-yl S-methyl carbonodithioate (8):** A stirred suspension of NaH (0.08 g, 3.63 mmol) in dry THF (4 mL) under N₂ atmosphere was treated with a solution of 16 (0.80 g, 1.81 mmol) in THF (4 mL) at 0 °C, CS₂ (0.21 mL, 2.72 mmol), MeI (0.17 mL, 2.72 mmol) was added at 0 °C and stirred for 2 h. Work up as described for 7 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 9:1) afforded 8 (0.85 g, 85%) as yellow syrup; [α]D = -87.5 (c 0.32, CHCl3); IR (neat): 3465, 2953, 2816, 1737, 1512, 1293, 1165, 761 cm⁻¹; ¹H NMR (300 MHz, CDCl₃): δ 1.07 (s, 9H, (CH₃)₃), 2.44 (s, 4H, SCH₃ and acetylenic-H), 3.11 (s, 3H, OCH₃), 3.93-4.05 (m, 3H, OCH₂ and H-2), 4.20-4.32 (m, 3H, OCH₂ and H-4), 4.71 (s, 1H, H-5), 6.04 (dd, 1H, J = 1.5, 3.3, 4.7 Hz, H-3), 7.31-7.42 (m, 6H, Ar-H), 7.61-7.72 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 214.1, 135.6 (4C), 133.3 (2C), 129.6 (2C), 127.7 (2C), 109.0, 87.4, 83.2, 80.8, 77.2, 74.2, 64.5, 54.8, 31.9, 29.7, 26.8, 22.7, 14.1; HRMS (ESI): m/z calculated for C₂₇H₃₅O₃S₂Si (M+H)⁺ 531.16897, found 531.16889.

**5-(tert.-Butyl-diphenylsilyloxyethyl)-2,2-dimethyl-(3aR,5R,6S,6aR)-perhydrofuro[2,3-d] [1,3]dioxol-6-ol (28):** To a stirred solution of diol 27 (2.4 g, 12.63 mmol) in CH₂Cl₂ (20 mL), imidazole (1.71 g, 25.26 mmol) was added and the reaction mixture was stirred at 0 °C. After 10 min, TBDPSCl (3.28 g, 12.63 mmol) and DMAP (0.01 g) were added and stirred for 2 h. Work up as described for 12 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) afforded 28 (3.8 g, 70%) as syrup; [α]D = -4.2 (c 0.86, CHCl₃); IR (neat): 3554, 3312, 2878, 1720, 1643, 1231, 1071, 1026, 967, 741 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): 1.05 (s, 9H, C(CH₃)₃), 1.33 (s, 3H, CH₃), 1.46 (s, 3H, CH₃), 3.96 (d, 1H, J = 2.5 Hz, H-5), 4.09-4.14 (m, 2H, OCH₂), 4.36 (s, 1H, H-6), 4.54 (d, 1H, J = 3.5 Hz, H-6a), 6.0 (d, 1H, J = 3.5 Hz, H-6b), 7.0 (d, 2H, J = 7.5 Hz, H-6c), 7.3-7.5 (m, 5H, Ar-H), 7.6 (d, 2H, J = 8.0 Hz, Ar-H), 7.7 (d, 1H, J = 8.0 Hz, Ar-H), 8.0 (d, 1H, J = 8.0 Hz, Ar-H).
1H, J = 3.5 Hz, H-3a), 7.38-7.44 (m, 6H, Ar-H), 7.66-7.71 (m, 4H, Ar-H); 13C NMR (CDCl₃, 75 MHz): δ 135.3 (2C), 135.2 (2C), 132.4 (2C), 129.8 (2C), 127.7 (2C), 111.2, 104.7, 85.2, 78.6, 76.1, 62.3, 26.3 (3C), 26.0 (2C), 18.9; HRMS (ESI): m/z calculated for C₂₄H₃₂NaO₅Si (M⁺+Na) 451.1916, found 451.1895.

(3aR,5R,6S,6aR)-Tetrahydro-2,2-dimethyl-6-(prop-2-ynyloxy)furo[2,3-d][1,3]dioxol-5-yl methoxy)(tert.-butyldiphenylsilane (29): A stirred suspension of NaH (0.36 g, 14.95 mmol) in dry THF (20 mL) under N₂ atmosphere was treated with a solution of 28 (3.20 g, 7.47 mmol) in THF (7 mL) at 0 °C and stirred for 15 min. Propargyl bromide (0.83 mL, 7.47 mmol) was added and stirred at room temperature for 4 h. Work up as described for 10 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) afforded 29 (2.80 g, 80%) as a liquid; [α]D = -16.3 (c 1.88, CHCl₃); IR (neat): 3312, 2897, 1754, 1598, 1232, 1012, 956, 783 cm⁻¹; 1H NMR (300 MHz, CDCl₃): 1.05 (s, 9H, C(CH₃)₃), 1.33-1.58 (m, 6H, 2xCH₃), 2.42 (t, 1H, J = 2.3 Hz, acetylenic-H), 3.69-3.94 (m, 2H, OCH₂), 4.13 (t, 1H, J = 2.3 Hz, H-5), 4.17-4.36 (m, 3H, OCH₂ and H-6), 4.65 (d, 1H, J = 3.7 Hz, H-6a), 5.87 (d, 1H, J = 3.5 Hz, H-3a), 7.35-7.44 (m, 6H, Ar-H), 7.66-7.71 (m, 4H, Ar-H); 13C NMR (CDCl₃, 75 MHz): δ 135.6 (2C), 135.5 (2C), 130.0 (2C), 129.7 (2C), 127.7 (2C), 111.7, 104.9, 84.6, 82.3, 80.9, 75.0, 67.8, 60.3, 57.7, 26.8 (3C), 26.2 (2C), 19.1; HRMS (ESI): m/z calculated for C₂₇H₃₄NaO₅Si (M⁺+Na) 489.20677, found 489.20490.

(2R,3R,4R,5S)-5-((tert.-Butyldiphenylsilyl)methyl)-tetrahydro-2-methoxy-4-(prop-2-ynyloxy)furan-3-ol (31): To a solution of 29 (1.0 g, 4.38 mmol) in dry MeOH (15 mL) under N₂ atmosphere 3 drops of conc. HCl was added at 0 °C and stirred for 6 h. Work up as described for 11 and purification of residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.8:8.2) afforded anomic mixture 30 (0.71 g, 80%) as a liquid, which was used as such for the next reaction.

To a stirred solution of 30 (1.50 g, 7.42 mmol) in CH₂Cl₂ (25 mL), imidazole (1.0 g, 14.8 mmol) was added and stirred at 0 °C. After 10 min, TBDPSI (1.93 g, 7.42 mmol) and DMAP (0.01 g) were added stirred at room temperature for 2 h. Work up as described for 12 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) afforded β-anomer as major anomer 31 (1.44 g, 44%) as syrup; [α]D = -25.1 (c 1.5,
CHCl₃); IR (neat): 3590, 3312, 2823, 1711, 1256, 852, 756 cm⁻¹; ¹H NMR (300 MHz, CDCl₃): δ 1.06 (s, 9H, C(CH₃)₃), 2.44 (t, 1H, J = 2.4 Hz, acetylenic-H), 2.70 (d, 1H, J = 2.4 Hz, -OH), 3.19 (s, 3H, OCH₃), 3.69-3.75 (m, 1H, H-5), 3.87-4.03 (m, 2H, OCH₂), 4.14 (s, 1H, H-4), 4.25 (q, 2H, J = 1.3, 2.6 Hz, OCH₂), 4.57 (m, 1H, H-3), 4.69 (s, 1H, H-2), 7.35-7.44 (m, 6H, Ar-H), 7.66-7.71 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 135.6 (4C), 130.0 (2C), 127.8 (4C), 108.7, 82.1, 80.5, 74.6, 69.6, 58.6, 54.9, 26.7 (3C), 19.1; HRMS (ESI): m/z calculated for C₂₅H₃₂NaO₅Si (M⁺+Na) 463.19112, found 463.19078.

O-(2R,3R,4R,5S)-5-((tert.-Butyldiphenyilsilyl)methyl)-tetrahydro-2-methoxy-4-(prop-2-ynyloxy)furan-3-yl S-methyl carbonodithioate (25): A stirred suspension of NaH (0.08 g, 3.63 mmol) in dry THF (10 mL) under N₂ atmosphere at 0 °C, a solution of 31 (0.80 g, 1.81 mmol) in THF (5 mL) was added and stirred at room temperature for 10 min. CS₂ (0.21 mL, 2.72 mmol) followed by MeI (0.17 mL, 2.72 mmol) were added stirred at room temperature for 2 h. Work up as described for 7 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1:9) afforded 25 (0.70 g, 70%) as light yellow liquid; [α]D = -20.46 (c 0.17, CHCl₃); IR (neat): 3323, 2808, 1754, 1479, 1198, 1026, 757 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ 1.06 (s, 9H, C(CH₃)₃), 2.41 (t, 1H, J = 2.4 Hz, acetylenic-H), 2.46 (s, 3H, SCH₃), 3.13 (s, 3H, OCH₃), 3.69 (d, 2H, J = 5.9 Hz, OCH₂), 4.06 (t, 1H, J = 2.4 Hz, H-5), 4.19 (t, 2H, J = 2.4 Hz, OCH₂), 4.31 (m, 1H, H-4), 4.69 (s, 1H, H-2), 5.99 (d, 1H, J = 5.0 Hz, H-3), 7.35-7.44 (m, 6H, Ar-H), 7.66-7.71 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 215.7, 135.8 (2C), 133.3 (2C), 129.9 (2C), 127.7 (4C), 109.2, 99.5, 85.2, 79.5, 74.6, 68.8, 58.5, 55.2, 26.8 (3C), 19.1; HRMS (ESI): m/z calculated for C₂₇H₃₅O₅S₂Si (M⁺+H) 531.16897, found 531.16949.

(((3aS,4R,6R,6aR)-Hexahydro-4-methoxy-3-methylenefuro[3,4-b]furan-6-yl)methoxy)(tert.-butyl)diphenylsilane (23): A solution of 25 (0.12 g, 0.22 mmol) in dry benzene (25 mL) under N₂ atmosphere was treated with n-Bu₃SnH (0.17 mL, 0.43 mmol) at room temperature and heated at reflux for 30 min. After 30 min, catalytic amount of AIBN was added at reflux and stirred for 12 h. Work up as described for 5 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) afforded 23 (0.07 g, 71%) as a colorless liquid; [α]D = -32.7 (c 0.31, CHCl₃); IR (neat): 2934, 2889, 1744, 1674, 1426, 1218, 1165, 767 cm⁻¹; ¹H NMR (300 MHz, CDCl₃): δ 1.05 (s, 9H, C(CH₃)₃), 3.32 (s, 1H, H-6), 127
Chapter II, Section-B, Experimental section

3.39 (s, 3H, OCH₃), 3.83 (d, 2H, J = 4.1 Hz, OCH₂), 4.25 (m, 2H, OCH₂), 4.61-4.68 (m, 2H, H-6a and H-3a), 4.96 (d, 1H, J = 6.0 Hz, H-4), 5.02 (bs, 2H, olefinic), 7.34-7.42 (m, 6H, Ar-H), 7.70-7.72 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 145.9, 135.6 (2C), 133.2 (2C), 129.6 (2C), 127.6 (4C), 106.9, 105.1, 85.1, 76.9, 73.6, 63.4, 55.2, 54.5, 26.7, 19.1; HRMS (ESI): m/z calculated for C_{25}H_{32}O_{4}NaSi (M⁺+Na) 447.19621, found 447.19538.

6-(4-Methoxybenzyloxy)-2,2-dimethyl-(3aR,5R,6S,6aR)-perhydrofuro[2,3-d][1,3]dioxol-5-(tert.-butyldiphenylsilyl)-methylether (32): A stirred suspension of NaH (0.42 g, 17.52 mmol) in dry THF (10 mL) under N₂ atmosphere was treated with a solution of 28 (3.0 g, 7.01 mmol) in THF (10 mL) at 0 °C and stirred for 30 min. PMBBr (1.54 mL, 7.71 mmol) was added to the reaction mixture at 0 °C and stirred at room temperature for 4 h. Reaction mixture was quenched with aq. NH₄Cl solution (10 mL) and extracted with EtOAc (2 x 30 mL). Organic layer was washed with aq. water (20 mL), brine (20 mL) and dried (Na₂SO₄). Solvent was evaporated and purified the residue by column chromatography (60-120 Silica gel, ethyl acetate: pet. ether, 0.5:9.5) to afford 32 (3.20 g, 83%) as a colorless syrup; [α]D = -21.25 (c 2.4, CHCl₃); IR (Neat): 3243, 2987, 2828, 1782, 1724, 1631, 1576, 1245, 1187, 1135, 1071, 873, 798, 671, 527 cm⁻¹; ¹H NMR (300 MHz, CDCl₃): δ 1.05 (s, 9H, (CH₃)₃), 1.25 (s, 3H, CH₃), 1.48 (s, 3H, CH₃), 3.79 (s, 3H, OCH₃), 3.86-3.98 (m, 2H, OCH₂), 4.03 (d, 1H, J = 2.6 Hz, H-6), 4.29 (m, 1H, H-5), 4.48-4.63 (m, 3H, H-6a and OCH₂), 5.88 (d, 1H, J = 3.4 Hz, H-3a), 6.82 and 7.22 (d, 2H each, J = 8.6 Hz, Ar-H), 7.30-7.42 (m, 6H, Ar-H), 7.60-7.70 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 159.2, 135.5 (4C), 129.1 (2C), 127.6 (4C), 113.7, 111.6, 105.0, 82.5, 81.1, 80.5, 71.9, 60.8, 55.1, 26.8 (3C), 26.3, 19.1; HRMS (ESI): m/z calculated for C_{32}H_{40}NaO_{6}Si (M⁺+Na) 571.2491, found 571.2512.

(((2R,3S,4R,5R)-3-(4-Methoxybenzyloxy)-tetrahydro-5-methoxy-4-(prop-2-ynyloxy)furan-2-yl)methoxy)(tert.-butyl) diphenylsilane (34a): To a solution of 32 (1.20 g, 3.87 mmol) in dry MeOH (15 mL) under N₂ atmosphere 3 drops of conc. HCl was added at 0 °C and stirred for 6 h. Work up as described for 11 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.8:8.2) afforded anomeric mixture 33 (0.75 g, 68%) as a liquid, which was used as such for the next reaction.
To a stirred solution of 33 (0.70 g, 2.46 mmol) in CH₂Cl₂ (5 mL), imidazole (0.33 g, 4.93 mmol) was added and stirred at 0 °C. After 10 min, TBDPSCI (0.64 mL, 2.46 mmol) and DMAP (0.01 g) were added and stirred at room temperature for 2 h. Work up as described for 12 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) afforded anomic mixture 33a (0.98 g, 76%) as syrup.

A stirred suspension of NaH (0.08 g, 3.45 mmol) in dry THF (3 mL) under N₂ atmosphere was treated with a solution of 33a (0.90 g, 1.72 mmol) in THF (5 mL) at 0 °C and stirred for 15 min. Propargyl bromide (0.25 mL, 1.72 mmol) was added to the reaction mixture at 0 °C and stirred at room temperature for 4 h. Work up as described for 10 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 1.2:8.8) afforded β-anomer as major anomer 34a (0.51 g, 53%) as a syrup; [α]D = -24.25 (c 2.7, CHCl₃); IR (neat): 3345, 3279, 2965, 1764, 1645, 1597, 1224, 1106, 1051, 986, 742 cm⁻¹; ¹H NMR (500 MHz, CDCl₃): δ 1.06 (s, 9H, (CH₃)₃), 2.27 (bs, 1H, H-7), 3.16 (s, 3H, OCH₃), 3.74 (s, 3H, Ar-OCH₃), 3.78 (bs, 1H, H-2), 3.82-3.93 (m, 4H, 2xOCH₂), 4.07 (d, 1H, J = 11.4 Hz, H-3), 4.23 (s, 2H, Ar-OCH₂), 4.44 (q, 1H, J = 5.9, 10.9 Hz, H-4), 4.81 (s, 1H, H-5), 6.70 (d, 2H, J = 7.9 Hz, Ar-H), 6.90 (d, 2H, J = 7.9 Hz, Ar-H), 7.27-7.44 (m, 6H, Ar-H), 7.64-7.71 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 158.8, 135.8 (2C), 135.5 (2C), 135.2 (2C), 134.7 (2C), 129.9, 129.5, 129.4, 128.9, 127.6, 113.5, 110.3, 82.6, 82.5, 80.0, 77.2, 71.2, 63.0, 55.1, 26.9, 19.1.

(2R,3S,4R,5R)-Tetrahydro-2-( tert.-butyl-diphenylsilyloxy)methyl-5-methoxy-4-(prop-2-ynyloxy)furan-3-ol (35): A solution of 34a (0.20 g, 0.35 mmol) in aq. CH₂Cl₂ (1:19, H₂O:CH₂Cl₂, 10 mL) was treated with DDQ (0.16 g, 0.71 mmol) and stirred at 0 °C for 2 h. Work up as described for 16 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate: pet. ether, 4:1) gave 35 (0.12 g, 76%) as a syrup; [α]D = -46.96 (c 0.66, CHCl₃); IR (neat): 3387, 2984, 2812, 1765, 1321, 771 cm⁻¹; ¹H NMR (300 MHz, CDCl₃): δ 1.06 (s, 9H, (CH₃)₃), 2.23 (bs, 1H, H-7), 3.19 (s, 3H, OCH₃), 3.86-3.91 (m, 2H, H-2 and H-3), 4.00-4.07 (m, 2H, OCH₂), 4.17 (s, 2H, OCH₂), 4.48 (q, 1H, J = 5.2, 9.4 Hz, H-4), 4.70 (s, 1H, H-5), 7.35-7.44 (m, 6H, Ar-H), 7.62-7.73 (m, 4H, Ar-H); ¹³C NMR (CDCl₃, 75 MHz): δ 135.6 (4C), 134.7 (2C), 129.6 (2C), 127.6 (2C), 109.1, 83.0, 81.1, 76.8, 63.2, 55.3, 26.5 (3C), 19.1; HRMS (ESI): m/z calculated for C₂₅H₃₂NaO₅Si (M⁺+Na) 463.19112, found 463.19086.
O-(2R,3S,4R,5R)-Tetrahydro-2-(tert.-butyl-diphenylsilyloxy)methyl)-5-methoxy-4-(prop-2-ynyloxy)furan-3-yl S-methyl carbonodithioate (26): A stirred suspension of NaH (0.08 g, 3.63 mmol) in dry THF (4 mL) under N\textsubscript{2} atmosphere was treated with a solution of 35 (0.80 g, 1.81 mmol) in THF (4 mL) at 0 °C and stirred at room temperature for 10 min, CS\textsubscript{2} (0.21 mL, 2.72 mmol) followed by MeI (0.17 mL, 2.72 mmol) were added at 0 °C and stirred at room temperature for 2 h. Work up as described for 7 and purification of the residue by column chromatography (60-120 Silica gel; ethyl acetate; pet. ether, 9:1) afforded 26 (0.81 g, 81%) as yellow syrup; [α]\textsubscript{D} = -36.71 (c 0.64, CHCl\textsubscript{3}); IR (neat): 3387, 2892, 2851, 1743, 1478, 1234, 1056, 779 cm\textsuperscript{-1}; \textsuperscript{1}H NMR (300 MHz, CDCl\textsubscript{3}): δ 1.01 (s, 9H, (CH\textsubscript{3})\textsubscript{3}), 2.33 (s, 3H, SCH\textsubscript{3}), 2.44 (bs, 1H, H-7), 3.03 (s, 3H, OCH\textsubscript{3}), 3.78 (m, 3H, OCH\textsubscript{2} and H-2), 4.15-4.23 (m, 1H, H-4), 4.33-4.44 (m, 2H, OCH\textsubscript{2}), 4.64 (s, 1H, H-5), 6.06 (dd, 1H, J = 1.5, 4.5, 6.4 Hz, H-3), 7.31-7.43 (m, 6H, Ar-H), 7.61-7.77 (m, 4H, Ar-H); \textsuperscript{13}C NMR (CDCl\textsubscript{3}, 75 MHz): δ 214.3, 135.8 (4C), 134.7 (2C), 129.8 (2C), 127.6 (2C), 109.2, 84.8, 80.8, 79.8, 77.2, 73.4, 62.2, 55.1, 31.9, 29.7, 26.8, 22.8, 19.1; HRMS (ESI): m/z calculated for C\textsubscript{27}H\textsubscript{35}O\textsubscript{5}S\textsubscript{2}Si (M\textsuperscript{+}+H) 531.16897, found 531.16965.
References:

SPECTRA
Spectrum 1: $^1$H NMR Spectrum of compound 12a in CDCl$_3$ (500 MHz)
$^{13}$C NMR Spectrum of compound 12a in CDCl$_3$ (75 MHz)
Spectrum 2: $^1$H NMR Spectrum of compound 7 in CDCl$_3$ (500 MHz)

$^{13}$C NMR Spectrum of compound 7 in CDCl$_3$ (75 MHz)
Spectrum 3: $^1$H NMR Spectrum of compound 5 in CDCl$_3$ (300 MHz)
$^{13}$C NMR Spectrum of compound 5 in CDCl$_3$ (75 MHz)
Spectrum 4: $^1$H NMR Spectrum of compound 15 in CDCl$_3$ (500 MHz)
$^{13}$C NMR Spectrum of compound 15 in CDCl$_3$ (75 MHz)
Spectrum 5: $^1$H NMR Spectrum of compound 15a in CDCl$_3$ (500 MHz)
$^{13}$C NMR Spectrum of compound 15a in CDCl$_3$ (75 MHz)
Spectrum 6: $^1$H NMR Spectrum of compound 8 in CDCl$_3$ (300 MHz)

$^{13}$C NMR Spectrum of compound 8 in CDCl$_3$ (75 MHz)
Spectrum 7: $^1$H NMR Spectrum of compound 29 in CDCl$_3$ (300 MHz)

$^{13}$C NMR Spectrum of compound 29 in CDCl$_3$ (75 MHz)
Spectrum 8: $^1$H NMR Spectrum of compound 31 in CDCl$_3$ (300 MHz)
$^{13}$C NMR Spectrum of compound 31 in CDCl$_3$ (75 MHz)
Spectrum 9: $^1$H NMR Spectrum of compound 25 in CDCl$_3$ (500 MHz)
$^{13}$C NMR Spectrum of compound 25 in CDCl$_3$ (75 MHz)
Spectrum 10: $^1$H NMR Spectrum of compound 23 in CDCl$_3$ (300 MHz)
$^{13}$C NMR Spectrum of compound 23 in CDCl$_3$ (150 MHz)
Spectrum 11: $^1$H NMR Spectrum of compound 34a in CDCl$_3$ (5300 MHz)
$^{13}$C NMR Spectrum of compound 34a in CDCl$_3$ (75 MHz)
Spectrum 12: $^1$H NMR Spectrum of compound 26 in CDCl$_3$ (300 MHz)
$^{13}$C NMR Spectrum of compound 26 in CDCl$_3$ (75 MHz)