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Chapter 3

Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors*

Introduction

The rare sugar 2-acetamido-2-deoxy-fucose (FucNAc) is a constituent monosaccharide of several bacterial capsular polysaccharides (CPS), including the *Staphylococcus aureus* type 5 and type 8 CPS,¹ the *S. aureus* Strain M type 1 CPS,² as well as *O*-antigenic polysaccharides from *Escherichia coli* strains (Figure 1).³,⁴ Both D- and L-enantiomers are found in Nature and they can be connected to other carbohydrate moieties through an α- or a β-glycosidic linkage. In order to chemically synthesize α-FucNAc-containing oligosaccharides, the C2-amino functionality is generally masked as a non-participating azido group to allow the formation of the 1,2-κα linkage.⁵

While 2-azido-2-deoxy fucosyl (FucN₃) donors have previously been used in oligosaccharide synthesis, lack of systematic knowledge regarding their reactivity and selectivity has resulted in relatively low yields and stereoselectivity. Notably, analogous L-fucosyl (Fuc) donors, are known to give highly α-selective glycosylation reactions, under a variety of conditions (also see Chapter 2). A general paradigm to account for the α-selectivity in fucosylations (and by extension, 2-azido-2-deoxy-fucosylations) is that 3,4-di-O-acyl protecting groups provide the desired selectivity through a remote participating effect, where one of the acyl groups coordinates with a transient oxocarbenium ion from the β-face, thereby only allowing α-facial attack of the incoming nucleophile. This Chapter describes the synthesis of a panel of six 1-phenylseleno-FucN₃ donors featuring a range of protecting groups at 3-O and 4-O, and investigation of their reactivity and selectivity in glycosylation reactions. The formation and stability of potential covalent reactive intermediates is investigated by low-temperature NMR. The influence of the nucleophilicity of the acceptor on the stereochemical outcome of the glycosylations is studied in detail through the use of a series ethanol acceptors, carrying no, one, two or three β-fluoride atoms. In contrast to the numerous studies on the reactivity of donor glycosides and the effect of donor reactivity on the outcome of a glycosylation reaction, the systematic study of acceptor reactivity is minimally explored, even though it is well known that
the nature of the acceptor can be of decisive influence for the outcome of a glycosylation reaction.\textsuperscript{30–35}

**Results and Discussion**

For this study six 1-FucN\textsubscript{3} donors 1-6, bearing either benzyl (Bn), benzyol (Bz) or tert-butyldimethylsilyl (TBS) groups on the 3-\textit{O} and 4-\textit{O} position were selected (Figure 2A). The influence of protecting groups on the reactivity of glycosyl donors has been long appreciated in carbohydrate chemistry. It has led to the ‘armed-disarmed’ concept, originally conceptualized by Fraser-Reid and co-workers.\textsuperscript{36} and to the ensuing establishment of relative reactivity values (RRVs) of glycosyl donors.\textsuperscript{22,37} The group of Bols has found that the use of multiple TBS protecting groups in a monosaccharide donor can ‘super-arm’ these donors, by forcing them in a more reactive conformation.\textsuperscript{38,39} Scanlan and co-workers have reported the synthesis and successful application of TBS-protected fucosyl donors in constructing \(\alpha\)-fucosyl linkages.\textsuperscript{40}

The set of acceptor alcohols used is depicted in Figure 2B. The set of partially fluorinated ethanol will be used to investigate how gradually diminishing nucleophilicity of the acceptor (going from ethanol to 2-mono-, 2,2-di- and 2,2,2-trifluoroethanol) affects the stereochemical outcome of the glycosylation reactions.\textsuperscript{35} Three secondary acceptors will be used: cyclohexanol, mannosyl acceptor 7, having an axially oriented hydroxyl group\textsuperscript{41} and mannose 8, with an equatorially oriented OH.\textsuperscript{42}

**Figure 2:** Donors (A) and acceptors (B) used in this study.
Donor synthesis

Synthesis of diol building block 12 commenced with the acetylation of commercially available L-fucose, according to the procedure of Roseman and co-workers (Scheme 1). Under these conditions, the formation of furanosides is avoided. Conversion of the crude peracetate 10 to the glycal 11 was achieved by bromination of the anomeric center, followed by zinc-mediated elimination (64% yield over 3 steps). Azidophenylselenylation of the fucal, following a protocol from Nifantiev and co-workers, led to a mixture of diastereomers, with the desired α-phenylseleno fuco-configured product prevailing. Deacetylation using Zemplén conditions, followed by crystallization of the desired diol from toluene/hexane afforded central building block 12 in 56% yield over 2 steps. Dibenzylation (1) and dibenzoxylation donors (2) were obtained using standard conditions in 85% and 90% yield, respectively. Silylation of 13 using TBSCl and DMAP in pyridine at 70 °C proceeded uneventfully, giving 5 in 85% yield, while the use of TBSCI and imidazole in DMF only resulted in mono-silylated product. ¹H-NMR analysis indicated that fucosazide 5 resides in a ‘normal’ ¹C₄ conformation, even though significant signal broadening was observed in the ¹³C-NMR spectrum. Donor 3 was obtained by tin-mediated regioselective benzylation, followed by benzoylation of the 4-O position, in 47% yield over two steps. Synthesis of donors 4 and 6 required more elaborate protecting group manipulations: tin-mediated para-methoxybenzylolation (81% yield), followed by benzylolation delivered intermediate 13 in 90% yield. Removal of the PMB ether was accomplished with a catalytic amount of HCl in 1,1,1,3,3,3-hexafluoro-iso-propanol (HFIP) to give 14 in 64% yield. Triethylsilane (TESH) was added as a scavenger to the reaction to prevent attack of the anomeric phenylseleno moiety on the generated para-methoxybenzyl cation. Benzylolation and silylation of 14 proceeded uneventfully to obtain donors 5 (96% yield) and 6 (92% yield).

Low-temperature NMR studies

In order to study potential reactive intermediates during glycosylation, low-temperature NMR studies were carried out. Donors 1 and 2 were selected, as they represent two ‘extremes’ of the four benzyl/benzoyl protected donors in terms of reactivity. As an activation method, the Ph₃SO/Tf₂O-mediated pre-activation protocol was selected. This method has been previously used, for the activation of selenoglycosides, and for the detection of reactive intermediates by low-temperature NMR spectroscopy on hemiacetal- and thioglycoside donors. Thus, a mixture of dibenzylated donor 1 and Ph₃SO (1.3 equivalents) in deuterated dichloromethane was treated with Tf₂O (1.3 equivalents) at -80 °C (Figure 3A). After recording a ¹H NMR spectrum (Figure 3B), two new anomeric signals appeared (δ: 6.06 and 6.10 ppm), which were assigned as...
\(\alpha\)-triflate 15 (\(J = 3.2 \text{ Hz}\)) and oxosulphonium triflate 17\(\alpha\) (\(J = 3.2 \text{ Hz}\)), respectively, based on their chemical shift.\(^{29}\)

**Scheme 1:** Synthesis of Fuc\(N_3\) donors.

\[\text{Reagents and conditions: a) } \text{Ac}_2\text{O}, \text{pyridine, 0-4 °C; b) } \text{HBr}, \text{AcOH, CH}_2\text{Cl}_2, 0-4 °C; c) } \text{Zn/Cu, N-methylimidazole, EtOAc, 70 °C (64%, 3 steps); d) } \text{(PhSe)}_2, \text{TMSN}, \text{Phi(OAc)}_2, \text{CH}_2\text{Cl}_2, -30 \rightarrow -10 °C; e) \text{Na, MeOH, 56%, 2 steps; f) } \text{BnBr, NaH (60% in oil), DMF, 0 °C (85% for 1, 90% for 13); g) } \text{BzCl, DMAP (cat.), CH}_2\text{Cl}_2, \text{pyridine, 0 °C (90% for 2, 96% for 4); h) } \text{TBSOTf, DMAP (cat.), pyridine, 0 → 70 °C (85% for 5, 92% for 6); i) } \text{Bu}_2\text{SnO, toluene, Dean-Stark, 140 °C, then BnBr, CsF, DMF; BzCl, DMAP (cat.), CH}_2\text{Cl}_2, \text{pyridine, 0 °C, (47%, 2 steps); j) } \text{Bu}_2\text{SnO, toluene, Dean-Stark, 140 °C; then PMBCl, CsF, Bu}_4\text{NBr, 120 °C (81%); k) } \text{HCl, TESH, HFP, CH}_2\text{Cl}_2 (64%).}\]

Further addition of \(\text{Ph}_2\text{SO}\) (to 2.0 eq.) resulted in an increase of the signal at \(\delta: 6.10 \text{ ppm, (Figure 3C),}\) reinforcing the presence of oxosulphonium triflate 17\(\alpha\)\(^{51}\) Activation of donor 1 with 4.0 equivalents of \(\text{Ph}_2\text{SO}\) resulted in the spectrum shown in Figure 3D. In this spectrum the signal at 6.06 ppm (the anomeric triflate) is not present but a new set of signals has appeared. Based on the doublet at 5.42 ppm, with a coupling coupling of 8.4 Hz, this resonance set was tentatively assigned to \(\beta\)-oxosulphonium triflate 17\(\beta\). In order to assess the stability of the reactive intermediates, the NMR probe was warmed up gradually by increments of 10 °C. Decomposition of \(\alpha\)-triflate 15 and \(\alpha/\beta\)-oxosulphonium triflates 17 started at -20 °C. Donor 2 was also converted to two new species (\(\delta: 6.31 \text{ ppm, and } \delta: 6.62 \text{ ppm, both with a coupling constant of 3.2 Hz})\), upon activation using the conditions described for dibenzylated donor 1 and these species were thus assigned as \(\alpha\)-triflate 16 and \(\alpha\)-oxosulphonium triflate 18 (Figure 3E). Incremental heating of the sample indicated that the onset of decomposition of both species started at 0 °C. It must be noted
that the observation of covalent intermediates (such as glycosyl triflates and -oxosulfonium triflates) does not rule out the presence of other intermediates, such as glycosyl oxocarbenium ions or their ion pairs.\textsuperscript{55} Such species are much higher in energy than covalent species and are therefore so short lived in organic media, that they are not observable on the NMR timescale.

**Figure 3:** Partial of the $^1$H-NMR spectra of activated FucN donors 1 and 2. A) The used donors and intermediates formed. B) Donor 1, 1.3 eq. Ph$_2$SO. C) Donor 1, 2.0 eq. Ph$_2$SO. D) Donor 1, 4.0 eq. Ph$_2$SO. E) Donor 2, 1.3 eq. Ph$_2$SO.

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**Model glycosylations**

After establishing the presence of covalent reactive species of donors 1 and 2, and the temperature of decomposition of these species, reaction conditions for model glycosylations could be established. All glycosylations were carried out under identical conditions. The selenoglycosyl donors were activated with the Ph$_2$SO/Tf$_2$O couple at -80 °C after which the temperature was allowed to raise to -60 °C to ensure complete activation of the donor fucosides. The mixtures were then cooled to -80 °C, prior to the addition of the acceptor and slow warming of the reaction mixture to -40 °C, at which temperature the reactions were stopped.\textsuperscript{36,37}
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors

First the series of primary ethanol acceptors was investigated and the results of these fucosaminylations are summarized in Table 1. Glycosylation of donors 1-6 with the series of ethanol (Table 1, Columns A-D) revealed a clear dependency of the stereochemical outcome of the glycosylations on the nucleophilicity of the acceptor alcohols. All donors show the same trend: with decreasing nucleophilicity (increasing amount of fluorine atoms in the acceptors) the α-selectivity increases. Where the more reactive donors (1, 5 and 6) react in a non-selective manner with the most nucleophilic acceptor, ethanol (Column A), the less reactive, benzoyl bearing fucosazide donors react with moderate β-selectivity. The glycosylations of the least reactive nucleophile, 2,2,2-trifluoroethanol all proceed with very good to excellent α-selectivity. The more reactive donors (1, 5 and 6) performed best in these glycosylation reactions, both in terms of yield and stereoselectivity.

Table 1: Glycosylations of 1-6 with model acceptors (B).

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Et</td>
<td>FEt</td>
<td>F₂Et</td>
<td>F₃Et</td>
<td>Cy</td>
<td>2-O-Man</td>
<td>3-O-Man</td>
</tr>
<tr>
<td>1</td>
<td>88% (1:1)</td>
<td>72% (1:1)</td>
<td>81% (2:1)</td>
<td>80% (19:1)</td>
<td>75% (2:1)</td>
<td>68% (19:1)</td>
<td>72% (19:1)</td>
</tr>
<tr>
<td>2</td>
<td>59% (1:3)</td>
<td>34% (1:2)</td>
<td>74% (3:2)</td>
<td>50% (10:1)</td>
<td>38% (1:9)</td>
<td>38% (4:1)</td>
<td>64% (19:1)</td>
</tr>
<tr>
<td>3</td>
<td>61% (1:3)</td>
<td>56% (1:1)</td>
<td>76% (3:1)</td>
<td>77% (7:1)</td>
<td>75% (1:4)</td>
<td>58% (10:1)</td>
<td>54% (19:1)</td>
</tr>
<tr>
<td>4</td>
<td>58% (1:3)</td>
<td>60% (2:3)</td>
<td>80% (1:1)</td>
<td>45% (19:1)</td>
<td>71% (1:4)</td>
<td>68% (4:1)</td>
<td>64% (10:1)</td>
</tr>
<tr>
<td>5</td>
<td>63% (2:5)</td>
<td>81% (2:3)</td>
<td>75% (5:2)</td>
<td>84% (19:1)</td>
<td>84% (1:3)</td>
<td>67% (19:1)</td>
<td>73% (19:1)</td>
</tr>
<tr>
<td>6</td>
<td>81% (1:1)</td>
<td>80% (1:1)</td>
<td>87% (2:1)</td>
<td>90% (19:1)</td>
<td>80% (1:2)</td>
<td>74% (19:1)</td>
<td>64% (9:1)</td>
</tr>
</tbody>
</table>

Next, the set of secondary alcohol acceptors was studied (Table 1, Columns E-G). Cyclohexanol reacts in a non-stereoselective manner with the reactive donor fucosides, and in a β-selective manner with the less reactive benzoylated donors (Column E). The condensations of the secondary carbohydrate acceptors 7 and 8 (Columns F and G) all proceed with good to excellent α-selectivity, again with the more reactive donors providing better α-selectivity than their less reactive counterparts.

Next, several modifications on the standard conditions were investigated. The use of additives to modulate selectivity in glycosylations has become increasingly prevalent in the past
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decade. To probe the influence of additives and solvents, the glycosylation of 1 with cyclohexanol was selected as a model system (Table 2). The use of a large excess of Ph₂SO in the activation of donor 1 led to the formation of equal amounts of both anomers of E1 in the coupling reaction. The low-temperature NMR experiments described above showed that the use of an large excess of Ph₂SO leads to the formation of a mixture of α/β-oxosulphonium triflates (17α/β) Apparently, the presence of a β-oxosulphonium triflate intermediate in the reaction mixture does not lead to increased α-product, indicating that oxosulphonium triflate 17β is not likely to be displaced in a direct, S₅₂-like manner.

Table 2: Influence of solvents and additives on the formation of E1.

<table>
<thead>
<tr>
<th>entry</th>
<th>Solvent</th>
<th>additive (eq.)</th>
<th>yield (α/β)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CH₂Cl₂</td>
<td>-</td>
<td>75% (2:1)</td>
</tr>
<tr>
<td>2</td>
<td>CH₂Cl₂</td>
<td>Ph₂SO (4)</td>
<td>53% (1:1)</td>
</tr>
<tr>
<td>3</td>
<td>CH₂Cl₂</td>
<td>Bu₄N OTf (3)</td>
<td>84% (2:5)</td>
</tr>
<tr>
<td>4</td>
<td>CH₂Cl₂/EtCN (19:1)</td>
<td>-</td>
<td>60% (1:2)</td>
</tr>
<tr>
<td>5</td>
<td>CH₂Cl₂/EtNO₂ (1:1)</td>
<td>-</td>
<td>56% (2:5)</td>
</tr>
<tr>
<td>6</td>
<td>CH₂Cl₂/Et₂O (1:1)</td>
<td>-</td>
<td>69% (1:5)</td>
</tr>
</tbody>
</table>

a. Instead of 1.3 equivalents.

The in situ anomerization of anomic leaving groups has been exploited in the synthesis of α-glycosidic bonds. Lemieux and co-workers were the first to show that the use of an excess of halide anions in a glycosylation mixture can be used to promote the anomerisation of an initially formed α-glycosyl halide into the more reactive β-halide (which does not benefit from an anomic effect), leading to an α-selective glycosylation by displacement of the reactive β-halide intermediate. To investigate whether excess triflate anion has a similar effect on the glycosylation of 1 with cyclohexanol, a glycosylation was carried out using 3 equivalents of Bu₄N OTf (entry 3). The glycosylation resulted in the formation of the β-product with moderate selectivity (α/β 2:5). This result shows that it is unlikely that the added Bu₄N OTf leads to an in situ anomerisation scenario as described above. This may be due to the low nucleophilicity of the triflate anion. The increased β-selectivity may be attributed to a shift in the equilibrium between
the covalent triflate species and the dissociated ion pairs towards the side of the anomeric α-triflate (15, Figure 3), due to the increased amount of triflate anion in the reaction mixture.

It has been long appreciated that the nature of the solvent(s) in glycosylations can have a profound effect on the outcome of the reaction, especially in terms of stereoselectivity. For example, nitrile solvents (acetonitrile and propionitrile are the most common) have often been used to promote the formation of β-glycosidic bonds.60,61 Reversely, the use of ethereal solvents generally leads to higher α-selectivity, supposedly through the intermediate formation of a species in which solvent molecules associate with the donor oxocarbenium ion on the β-face of the donor glycoside.62,63 The use of propionitrile led to increased β-product (entry 4). The large ratio of CH₂Cl₂ to EtCN (19:1) in this pre-activation protocol was used to prevent Ritter-type byproducts arising from attack of the acceptor on the nitrile spcarbon, as previously observed in the synthesis of β-L-rhamnosides.61 A mixture of CH₂Cl₂ and EtNO₂, in a ratio of 1:1, also led to increased β-selectivity. This may be due to the coordinating ability of the nitro group. Interestingly, the use of a 1:1 CH₂Cl₂/Et₂O mixture for the glycosylation of 1 and cyclohexanol did not lead to the formation of more α-product (entry 6). Rather, more β-product was formed, in contrast to the well-documented α-directing effect of Et₂O in glycosylations. An explanation can perhaps be sought in the decreased polarity of the CH₂Cl₂/Et₂O mixture compared to pure CH₂Cl₂.

A mechanistic picture

From the low-temperature NMR studies and the model glycosylation reactions, a general mechanism can be formulated (Scheme 2A). Upon activation of the phenylseleno moiety, a pool of reactive intermediates can be generated,64 with α-configured anomeric (oxosulphonium)triflate 20a acting as a ‘reservoir’ from which more reactive oxocarbenium ions (e.g. 21) can transiently form.55 As shown above, the nature of the acceptor is fundamental in the outcome of glycosylation stereoselectivity.35 A highly nucleophilic acceptor (such as ethanol, 2-fluoroethanol or cyclohexanol) is able to react with the covalent species 20, and produces mainly the β-product via direct displacement of the triflate (or oxosulphonium triflate) leaving group. On the other side, less nucleophilic acceptors (2,2,2-trifluoroethanol, or mannosyl acceptors 7 and 8) are less prone to directly displace a covalently bound leaving group (or tightly associated anion) and react preferentially via a more loosely associated ion pair, in an SN1-like mechanism. While the NMR studies on the reactive intermediates has revealed that β-linked oxosulphonium triflates may be formed during the reaction, they do not lead to increased α-product, diminishing the possibility that they participate in an Sn2-like reaction pathway. Likewise, the increased concentration of triflate anion (see Table 3, entry 3) did not lead to more α-product. It is possible that the triflate
anion influences the equilibrium between the α-triflate and dissociated glycosyl ion pairs, shifting it towards the covalent species, leading by the higher β-selectivity observed.

**Scheme 2:** A) Proposed mechanism for 2-azidofucosylation based on pre-activation. B) (De)stabilizing interactions in the two possible oxocarbenium ion conformers 23 and 24.

The nature of the protecting groups on the 3-Ο and 4-Ο positions influence the stability of the reactive intermediates. Electron-withdrawing benzoyl groups stabilize covalent intermediates, reflected by the higher decomposition temperature of dibenzoylated FucN\textsubscript{3} triflate 16 compared to dibenzylated analogue 15 (Figure 3). This increased stability leads to the superior β-selectivity of donor 2, as compared to the other donors used in this study, especially when reacted with highly reactive acceptors (see Table 2, entry 2).

It is now well established that the conformation of an intermediate oxocarbenium ion can be of decisive influence on the stereochemical outcome of a glycosylation reaction. Oxocarbenium ion 21, transiently formed from the covalent triflate or oxosulphonium triflate species, likely adopts a half-chair conformation (Scheme 2B), since this conformation best accommodates the flat oxocarbenium ion moiety.\textsuperscript{65,66} When the two possible half-chair conformers are considered, it appears that \textsuperscript{3}H\textsubscript{4} oxocarbenium ion 24 benefits from stabilization by electron donation of the lone pair electrons, of the C4-oxygen, which is placed in an axial position.\textsuperscript{67,68} In addition, the axial C-2-H-2 bond can stabilize the flanking oxocarbenium ion through hyperconjugation and the C-5 methyl group, incapable of any electronic stabilization, adopts a favored pseudo-equatorial
orientation. Top side attack of this oxocarbenium ion proceeds via a chair-like transition state to provide the α-product. The alternative 4H3 half-chair 23 can benefit from stabilization by the axially placed C-3-O substituent. It lacks the hyperconjugative stabilization of the C-2-H-2 bond, and the C-6 is placed in an unfavorable pseudo-axial orientation, where it experiences unfavorable steric interactions with the C3-substituent. In addition, attack of this half chair oxocarbenium ion on the bottom face would lead to the development of extra 1,3-diaxial interactions between the incoming nucleophile and the C-3 and C-6 substituents.

**Conclusion**

This Chapter has described an investigation into the reactivity and selectivity of phenylseleno FucN3 donors. In total, six differentially protected FucN3 donors, bearing benzyl, benzoyl or TBS groups were synthesized and subsequently investigated in glycosylation reactions with seven acceptors. Low-temperature NMR studies of dibenzylated (1) and dibenzoyletylated donor 2 revealed the formation of two reactive intermediates upon activation with Ph3S0 and Tf2O, and the structures were assigned as the corresponding α-glycosyl triflates and – oxosulfonium triflates. The model glycosylations showed a dependency of the nature of protecting groups on stereoselectivity, with more reactive donors providing higher α-selectivity. The nature of the acceptor proved to be critical to the glycosylation outcome, as more reactive acceptors generally gave more β-product, while less reactive acceptors (including carbohydrate acceptors) were more α-selective. This has been rationalized with a mechanistic pathway in which the more nucleophilic acceptors are able to react with covalent α-FucN3 triflates in a S$_{N}2$-like fashion, giving the β-product, while less nucleophilic acceptors preferentially react via a S$_{N}1$-like mechanism, through the intermediacy of a 3H$_{E}$-like oxocarbenium ion.
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Experimental

General procedures
All reactions were carried out in oven-dried glassware (85 °C). Prior to reactions, traces of water and solvent were removed by co-evaporation with toluene where appropriate. Reactions sensitive to air or moisture were carried out under an atmosphere of argon (balloon). Solvents for reactions were of reagent grade and stored over 4Å molecular sieves (3Å for CH₂Cl₂, MeOH and MeCN), except pyridine and DMF. NET₃ was stored over KOH pellets. Tf₂O used in glycosylations was dried over P₂O₅ (~3 hours), followed by distillation, and stored in a Schlenk flask at -20 °C. All other chemicals were used as received. Reaction progress was monitored using aluminium-supported silica gel TLC plates (Merck, Kieselgel 60, with fluorescent indicator); visualization was carried out by irradiation with UV light (λ: 254 nm), followed by spraying with 20% H₂SO₄ in EtOH (w/v) or Hanessian’s stain ((NH₄)₆Mo₇O₄₀.4H₂O, 25 g/L; (NH₄)₄Ce(SO₄)₂·2H₂O, 10 g/L; in 10%aq. H₂SO₄). Column chromatography was carried out using silica gel (Screening Devices, 0.040-0.063 mm). Size-exclusion chromatography was carried out using Sephadex LH-20 (GE Healthcare). NMR spectra were recorded on Bruker AV-400, DMX-400 or AV-500 instruments. Chemical shifts (δ) are reported in ppm relative to Me₄Si (δ: 0.00 ppm) or residual solvent signals. NMR spectra were recorded at ambient temperature, and samples were prepared in CDCl₃ unless noted otherwise. ^13C-APT spectra are ¹H decoupled. Structural assignment was achieved using HH-COSY and HSQC 2D experiments. Coupling constants of anomic carbon atoms (J_H1,C1) were determined using HMBC-GATED experiments. Infrared spectra were recorded with a Shimadzu FTIR 8300 instrument. Wavenumbers (υ) are reported in cm⁻¹. HRMS spectra were recorded on a Thermo Finnigan LCQ Orbitrap instrument.

3,4-di-O-acetyl-l-fucal (11)

To a stirred, ice-cooled mixture of Ac₂O (120 mL, 1.27 mol, 14 eq.) and pyridine (150 mL) was added l-fucose (15 g, 91 mmol, 1 eq.), in small portions, over the course of 15-20 minutes. The mixture was stirred at 0-4 °C overnight, after which TLC analysis (PE/EtOAc, 3:2 v/v) indicated complete consumption of the starting material. The mixture was poured on ice-water and stirred until the ice had melted. The mixture was extracted with CH₂Cl₂ (2x), the combined organics were washed with sat. aq. NH₄Cl solution (3x), water (2x), and brine (1x), dried over MgSO₄, filtered and concentrated in vacuo. The residue was coevaporated with toluene (3x) to remove residual
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pyridine. The crude mixture thus obtained was dissolved in CH₂Cl₂ (360 mL, 0.25 M) and cooled to 0 °C. To this solution was added HBr (33% in AcOH, 130 mL) in a dropwise fashion and the resulting solution was stirred at 0 °C until TLC analysis (CH₂Cl₂) indicated complete conversion of the starting material. The mixture was poured on ice-water and stirred until the ice had melted. The mixture was partitioned and the aqueous extracted with CH₂Cl₂ (2x). The combined organic phases were washed with sat. aq NaHCO₃ solution (2x), water (1x) and brine (1x), dried over MgSO₄, filtered and concentrated in vacuo. The residue was co-evaporated with toluene (1x) to remove excess acetic acid, and subsequently dissolved in EtOAc (300 mL, 0.3 M). The mixture was added to a mixture of freshly prepared Zn/Cu couple (30 g of Zn, 455 mmol, 5 eq.) and N-methylimidazole (7.3 mL, 91 mmol, 1 eq.) in EtOAc (300 mL). The mixture was heated to 70 °C and stirred until TLC analysis (PE/EtOAc, 7:3 v/v) indicated complete consumption of the anomic bromide. The reaction mixture was cooled to room temperature, filtered over a bed of celite, and the resulting solution concentrated in vacuo. The product was obtained from the residue by column chromatography (PE/EtOAc/NEt₃, 95:5:1 → 90:10:1 v/v/v) in 64% yield (12.5 g, 58.4 mmol). 1H NMR (400 MHz) δ: 6.47 (dd, 1H, J = 1.6 Hz, 6.4 Hz, H-1); 5.59-5.58 (m, 1H, H-3); 5.29 (d, 1H, J = 4.4 Hz, H-4); 4.66-4.63 (m, 1H, H-2); 4.22 (q, 1H, J = 6.4 Hz); 2.17 (s, 3H, CH₃Ac); 2.02 (s, 3H, CH₃Ac); 1.28 (d, 3H, J = 6.4 Hz, H-6). 13C-APT NMR (100 MHz) δ: 170.7, 170.4 (COAc); 146.1 (C-1); 98.2 (C-2); 71.5 (C-5); 66.2 (C-4); 65.0 (C-3); 20.9, 20.7 (CH₃Ac); 16.5 (C-6).

Phenyl 2-azido-2-deoxy-1-seleno-α-L-fucopyranoside (12)

A solution of 3,4-di-O-acetyl-L-fucal 11 (12.5 g, 58.4 mmol, 1.0 eq.) and (PhSe)₂ (18.2 g, 58.4 mmol, 1.0 eq.) in CH₂Cl₂ (300 mL, 0.2 M) was degassed by sonication (30 minutes) before being cooled to -30 °C. Added were PhI(OAc)₂ (18.8 g, 58.4 mmol, 1.0 eq.) and TMSN₃ (15 mL, 116.8 mmol, 2.0 eq.). The mixture was stirred for 1 hour at -30 °C and subsequently at -20 °C overnight. The mixture was added cyclohexene (~15 mL) and the mixture was allowed to warm to room temperature. The bright orange solution was concentrated in vacuo and the brown residual oil was subjected to column chromatography (PE/EtOAc, 1:0 → 9:1 v/v) to separate the lipophilic impurities from the carbohydrate fraction. The latter was concentrated and suspended in MeOH (190 mL, 0.3 M), after which NaOMe (0.31 g, 5.8 mmol, 0.1 eq.) was added. The mixture was stirred overnight, after which TLC analysis (PE/EtOAc, 1:1 v/v) showed complete conversion of the starting material. The reaction mixture was neutralized by addition of ion-exchange resin (Amberlite IR-120, H⁺ form). The resin was filtered and the filtrate concentrated in vacuo. The
solid thus obtained was crystallized from toluene to obtain the title compound as an amorphous solid (11.1 g, 33.8 mmol, 58%). 1H NMR (400 MHz, acetone-d6) δ: 7.62-7.57 (m, 2H, CH_arom); 7.32-7.28 (m, 3H, CH_arom); 5.96 (d, 1H, J = 5.2 Hz, H-1); 4.29 (q, 1H, J = 6.4 Hz, H-5); 4.40 (dd, 1H, J = 5.2 Hz, 10.4 Hz, H-2); 3.82-3.79 (m, 2H, H-3, H-4); 1.17 (d, 3H, J = 6.4 Hz, H-6). 13C-APT NMR (100 MHz, acetone-d6); 135.4 (CH_arom); 130.1 (C_qarom); 129.8, 128.3 (CH_arom); 86.7 (C-1); 72.4, 72.2 (C-3, C-4); 70.2 (C-5); 62.6 (C-2); 16.5 (C-6). IR (neat) ν: 3279, 2100, 1578, 1252, 1094, 1059. HRMS: [M-N₂+H]^+ calculated for C₁₂H₁₆NO₃Se: 302.02999; found 302.02914.

**Phenyl 2-azido-3,4-di-O-benzyl-2-deoxy-1-seleno-α-L-fucopyranoside (1)**

![Phenyl 2-azido-3,4-di-O-benzyl-2-deoxy-1-seleno-α-L-fucopyranoside (1)](image)

To a stirred solution of 12 in DMF (8 mL, 0.25 M) were added benzyl bromide (0.71 mL, 6.0 mmol, 3.0 eq.) and Bu₄Nl (0.15 g, 0.4 mmol, 0.2 eq.). The mixture was cooled in an ice-bath and NaH (60% w/w in oil, 0.32 g, 8.0 mmol, 4.0 eq.) was added. The mixture was stirred until TLC analysis (PE/EtOAc, 9:1 v/v) indicated complete consumption of the starting material (≤ 3 hours). Excess NaH was quenched by slow addition of cold water until gas evolution ceased. The mixture was diluted with water and Et₂O, and the aqueous phase was washed twice with Et₂O. The combined ethereal phases were washed with brine (1x), dried over MgSO₄, filtered and concentrated in vacuo. The residue was purified by column chromatography (PE/Et₂O 1:0 → 9:1) to furnish the title compound as an oil which solidified on standing, in 85% yield (0.87 g, 1.7 mmol). 1H NMR (400 MHz) δ: 7.57-7.47 (m, 2H, CH_arom); 7.45-7.22 (m, 13H, CH_arom); 5.93 (d, 1H, J = 5.2 Hz, H-1); 4.92 (d, 1H, J = 11.2 Hz, PhCH₂); 4.80-4.73 (m, 2H, PhCH₂); 4.61 (d, 1H, J = 11.6 Hz, PhCH₂); 4.35 (dd, 1H, J = 5.2 Hz, 9.8 Hz, H-2); 4.22 (q, 1H, J = 6.4 Hz, H-5); 3.75-3.72 (m, 2H, H-3, H-4); 1.13 (q, 3H, J = 6.4 Hz, H-6). 13C-APT NMR (100 MHz) δ: 138.1, 137.4 (C_qarom); 134.3, 129.0, 128.6, 128.3, 128.1, 128.0, 127.8, 127.7, 127.6 (CH_arom); 85.5 (C-1); 80.6, 75.7 (C-3, C-4); 75.0, 72.5 (PhCH₂); 69.4 (C-5); 60.9 (C-2); 16.5 (C-6). IR (neat) v: 2882, 2112, 1474, 1298, 1101, 1063, 1047. HRMS: [M-N₂+H]^+ calculated for C₂₆H₂₆NO₃Se: 482.12289; found 482.12286.

**Phenyl 2-azido-3,4-di-O-benzoyl-2-deoxy-1-seleno-α-L-fucopyranoside (2)**

![Phenyl 2-azido-3,4-di-O-benzoyl-2-deoxy-1-seleno-α-L-fucopyranoside (2)](image)
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors

To a stirred solution of $\mathbf{12}$ (0.66 g, 2.0 mmol, 1.0 eq.) in CH$_2$Cl$_2$/pyridine (3:1 v/v, 8 mL, 0.2 M) was slowly added BzCl (0.7 mL, 6.0 mmol, 3.0 eq.), followed by DMAP (0.05 g, 0.4 mmol, 0.2 eq.). The mixture was stirred until TLC analysis (PE/EtOAc, 4:1 v/v) indicated complete conversion of the starting material (~3 hours). The reaction was quenched with MeOH and the mixture was diluted with CH$_2$Cl$_2$, washed (1 M aq. HCl, 2x; sat. aq. NaHCO$_3$, 1x; brine, 1x), dried over MgSO$_4$, filtered and concentrated in vacuo. The residue was subjected to column chromatography (PE/EtOAc, 1:0 → 4:1) to furnish the title compound in 90% yield (0.96 g, 1.79 mmol). $^1$H NMR (400 MHz) $\delta$: 7.25-8.15 (m, 15H, $CH_{arom}$), 6.12 (d, 1H, $J = 5.2$ Hz, H-1), 5.76 (d, 1H, $J = 2.8$ Hz, H-4), 5.51 (dd, 1H, $J = 3.2$, 10.8 Hz, H-3), 4.53 (dd, 1H, $J = 5.6$, 10.8 Hz, H-2), 4.73 (q, 1H, $J = 6.4$ Hz, H-5), 1.19 (d, 3H, $J = 6.4$ Hz, H-6); $^{13}$C-APT NMR (100 MHz) $\delta$: 165.7, 165.4 ($CO_{bz}$), 134.9-127.2 ($CH_{arom}$), 84.6 (C-1), 72.4 (C-3), 70.8 (C-4), 68.0 (C-5), 59.6 (C-2), 16.0 (C-6). IR (thin film) $\nu$: 3061, 2984, 2108, 1724, 2953, 2930, 2856, 2106, 1472, 1252, 1115, 1067, 1022. HRMS: [M-N$_2$+H]$^+$ calculated for C$_{26}$H$_{24}$NO$_5$Se: 510.08142; found 510.08194.

Phenyl 2-azido-2-deoxy-3,4-di-O-(tert-butyldimethylsilyl)-1-seleno-$\alpha$-l-fucopyranoside (5)

A 100 mL three-necked flask was equipped with a septum, a gas inlet and a Liebig condenser fitted with a drying tube. Under a flow of N$_2$ gas, the flask was charged with a solution of $\mathbf{12}$ (1.31 g, 4.0 mmol, 1.0 eq.) in pyridine (20 mL, 0.2 M). At 0 °C, added was DMAP (98 mg, 0.8 mmol, 0.2 eq.) followed by TBSOTf (3.7 mL, 16.0 mmol, 4.0 eq., in a dropwise fashion). The mixture was heated to 70 °C and stirred for 16 hours, after which TLC analysis (PE/Et$_2$O, 19:1 v/v) showed complete conversion of the starting material. The reaction was cooled to rT, quenched with MeOH and the mixture diluted with EtOAc. The mixture was washed with 10% aq. CuSO$_4$ solution (2x), H$_2$O and brine, dried over MgSO$_4$, filtered and concentrated in vacuo. Purification by column chromatography (PE/Et$_2$O, 1:0 → 49:1 v/v) furnished the title compound as a light-yellow oil in 85% yield (3.4 mmol, 1.90 g). $^1$H NMR (CD$_2$Cl$_2$, 193 K) $\delta$: 7.53 (d, 2H, $J = 7.6$ Hz, $CH_{arom}$); 7.27-7.25 (m, 3H, $CH_{arom}$); 5.89 (d, 1H, $J = 5.2$ Hz, H-1); 4.21 (q, 1H, $J = 6.4$ Hz, H-5); 4.06 (dd, 1H, $J = 4.8$ Hz, 10.0 Hz, H-2); 3.70-3.67 (m, 2H, H-3, H-4); 1.06 (d, 3H, $J = 6.0$ Hz, H-6); 0.90, 0.82 (s, 9H, $CH_{3, tBu}$); 0.14, 0.11, 0.09, 0.03 (s, 3H, $CH_{3,Me}$). $^{13}$C-APT NMR (CD$_2$Cl$_2$, 193 K) $\delta$: 134.3, 128.7 ($CH_{arom}$); 128.0 ($C_{aq,arom}$); 127.4 ($CH_{arom}$); 85.3 (C-1); 73.6, 72.9 (C-3, C-4); 69.5 (C-2); 61.6 (C-5); 25.5, 25.3 ($CH_{3, tBu}$); 18.1, 17.8 ($C_{q, tBu}$); 16.6 (C-6); -4.3, -4.7, -5.3, -5.3 ($CH_{3,Me}$). IR (thin film) $\nu$: 2953, 2930, 2856, 2106, 1472, 1252, 1115, 1067, 1022. HRMS: [M-N$_2$+H]$^+$ calculated for C$_{26}$H$_{46}$NO$_5$SeSi$_2$: 530.20195; found 530.20166.
Dial 12 (0.66 g, 2.0 mmol, 1.0 eq.) was suspended in toluene (7 mL, 0.3 M). Bu3SnO (0.50 g, 2.0 mmol, 1.0 eq.) was added and the mixture was heated to 140 °C for 3 hours, during which a clear reaction mixture was obtained. The mixture was concentrated in vacuo and co-evaporated once with dry toluene. The mixture was dissolved in DMF (9 mL, 0.2 M), and BnBr (0.26 mL, 2.2 mmol, 1.1 eq.) and CsF (0.33 g, 2.2 mmol, 1.1 eq.), and the mixture was stirred overnight, after which TLC analysis indicated conversion of the starting material (PE/EtOAc, 7:3 v/v). The reaction was diluted with H2O, extracted (Et2O, 3x), the combined ethereal phases were washed (brine, 1x), dried over MgSO4, filtered and concentrated in vacuo. The residue was passed over a small column (PE/EtOAc, 1:0 → 4:1 v/v) to obtain the 3-O-benzylated product (0.42 mmol, 1 mmol, 50%). 1H NMR (400 MHz) δ: 7.59-7.56 (m, 2H, CHarom); 7.42-7.24 (m, 8H, CHarom); 5.89 (d, 1H, J = 5.2 Hz, H-1); 4.76 (d, 1H, J = 11.2 Hz, PhCH); 4.69 (d, 1H, J = 11.2 Hz, PhCH2); 4.30 (q, 1H, J = 6.8 Hz, H-5); 4.17 (dd, 1H, J = 5.2 Hz, 10.4 Hz, H-2); 3.88 (s, 1H, H-4); 3.70 (dd, 1H, J = 3.2 Hz, 10.4 Hz, H-3); 2.36 (s, 1H, 3-OH); 1.26 (d, 3H, J = 6.8 Hz, H-6). 13C-APT NMR (100 MHz, CDCl3) δ: 137.1 (Cq-arom), 134.5, 129.2, 128.9, 128.5 (CHarom), 128.2 (Cq-arom), 127.9 (CHarom), 85.3 (C-1), 79.3 (C-3), 72.3 (CH2 Bn), 68.7 (C-The intermediate was dissolved in CH2Cl2/pyridine (4:1 v/v, 5 mL, 0.2 M) and at 0 °C was added BzCl (0.14 mL, 1.2 mmol, 1.2 eq.) and DMAP (12 mg, 0.1 mmol, 0.1 eq.). After TLC analysis (PE/EtOAc, 9:1 v/v) indicated complete conversion of the starting material (~1 hour), the mixture was quenched by the addition of water. The mixture was diluted with CH2Cl2 washed (1M aq. HCl, 2x; sat. aq. NaHCO3 1x; H2O 1x; brine 1x), dried over MgSO4 filtrated and concentrated under reduced pressure. Purification by column chromatography (PE/EtOAc, 17:3 v/v) afforded the title compound (0.49 g; 0.93 mmol; 47% over 2 steps). 1H NMR (400 MHz) δ: 8.09-8.04 (m, 4H, CHarom), 7.64-7.20 (m, 11H, CHarom), 6.00 (d, 1H, J = 5.2 Hz, H-1), 5.71 (d, 1H, J = 2.8 Hz, H-4), 4.85 (d, 1H, J = 10.8 Hz, PhCH3), 4.57 (d, 1H, J = 10.8 Hz, PhCH2), 4.52 (q, 1H, J = 6.4 Hz, H-5), 4.26 (d, 1H, J = 5.2 Hz, J = 10.4 Hz, H-2), 3.90 (dd, 1H, J = 3.2 Hz, J = 10.0 Hz, H-3), 1.16 (d, 3H, J = 6.4 Hz, H-6); 13C-APT NMR (100 MHz) δ: 166.0 (COO), 136.9 (Cq-arom), 134.7-127.7 (CHarom), 85.1 (C-1), 77.5 (C-3), 71.6 (PhCH2), 69.4 (C-4), 68.1 (C-5), 60.5 (C-2), 16.2 (C-6). IR (thin film) ν: 3061, 2984, 2997, 2108, 1719, 1452, 1263, 1109, 1078, 1062, 1024. HRMS: [M-N2+H]+ calculated for C26H22NO3Se: 496.10216; found 496.10233.
**Phenyl 2-azido-4-O-benzyl-2-deoxy-3-O-(para-methoxybenzyl)-1-seleno-α-L-fucopyranoside (13)**

In a three-necked flask, equipped with a Dean-Stark trap, a suspension of diol 12 (4.27 g, 13 mmol, 1.0 eq.) and Bu₂SnO (3.40 g, 13.7 mmol, 1.05 eq.) in toluene (65 mL, 0.2 M) was heated to 140 °C for 1 hour. The resultant clear, brown solution was cooled to 60 °C, and added were Bu₄NBr (4.42 g, 13.7 mmol, 1.05 eq.), CsF (2.08 g, 13.7 mmol, 1.05 eq.) and PMBCl (1.9 mL, 13.7 mmol, 1.05 eq.). The mixture was heated to 120 °C for ~2 hours, after which TLC analysis (PE/EtOAc, 3:2 v/v) indicated complete conversion of the starting diol. The mixture was cooled to room temperature, KF (10% in H₂O, w/v) was added and stirred vigorously for ~15 minutes. The aqueous phase was extracted (EtOAc, 2x), the combined organic fractions washed (brine 1x), dried over MgSO₄, filtered and concentrated in vacuo. Purification by column chromatography (PE/EtOAc, 1:0 → 4:1) furnished the 3-O-PMB protected intermediate as a yellow oil in 81% yield (4.71 g, 10.5 mmol).

1H NMR (400 MHz) δ: 7.58-7.56 (m, 2H, CH₃Ar); 7.34-7.24 (m, 5H, CH₃Ar); 6.93-6.87 (m, 2H, CH₃Ar); 5.87 (d, 1H, J = 5.2 Hz, H-1); 4.68 (d, 1H, J = 10.8 Hz, PhCH₂); 4.62 (d, 1H, J = 10.8 Hz, PhCH₂); 4.26 (q, 1H, J = 6.4 Hz, H-5); 4.14 (dd, 1H, J = 5.2 Hz, 10.2 Hz, H-2); 3.83 (d, 1H, J = 2.4 Hz, H-4); 3.81 (s, 3H, OCH₃); 3.68 (dd, 1H, J = 3.2 Hz, 10.4 Hz, H-3); 1.25 (d, 3H, J = 6.4 Hz, H-6).

13C-APT NMR (100 MHz) δ: 159.6 (CqAr); 134.4, 134.3, 129.7, 129.0 (CHAr); 129.0, 128.6 (CqAr); 127.7, 114.0 (CHAr); 85.2 (C-1); 78.8 (C-3); 71.7 (PhCH₂); 68.5, 68.4 (C-4, C-5); 60.0 (C-2); 55.2 (OCH₃); 16.0 (C-6). IR (thin film) ν: 3441, 2897, 2106, 1612, 1512, 1246, 1088, 1063, 1031. HRMS: [M+H]+ calculated for C₂₀H₂₄N₃O₆Se: 450.09265; found 450.09232. A solution of the intermediate building block (1.56 g, 3.48 mmol, 1.0 eq.) and BnBr (0.83 mL, 6.96 mmol, 2.0 eq.) in DMF (12 mL, 0.3 M) was cooled to 0 °C. Added was NaH (60% dispersion in oil, 0.21 g, 5.22 mmol, 1.5 eq.) and the mixture was allowed to reach room temperature. After ~3 hours, TLC analysis (PE/EtOAc, 9:1 v/v) indicated complete conversion of the starting material and the reaction was quenched by slow addition of water. After gas evolution had ceased, the mixture was partitioned between water and Et₂O. The aqueous phase was extracted (Et₂O, 2x), and the combined ethereal phases were washed (brine, 1x), dried over MgSO₄, filtered and concentrated in vacuo. Purification by column chromatography (PE/Et₂O, 1:0 → 9:1) delivered the title product as a colorless oil (1.68 g, 3.12 mmol, 90%). 1H NMR (400 MHz) δ: 7.57-7.56 (m, 2H, CH₃Ar); 7.36-7.23 (m, 10H, CH₃Ar); 6.92 (d, 2H, J = 8.8 Hz, CH₃Ar); 5.91 (d, 1H, J = 5.2 Hz, H-1); 4.94 (d, 1H, J = 11.6 Hz, PhCH₂); 4.72-4.66 (m, 2H, PhCH₂); 4.60 (d, 1H, J = 11.6 Hz, PhCH₂); 4.32 (dd, 1H, J = 5.2 Hz, 10.2 Hz, H-2); 4.21 (q, 1H, J = 6.4 Hz, H-5); 3.82 (s, 3H, OCH₃); 3.73-3.68 (m, 2H, H-3, H-4). 13C-APT NMR (100 MHz) δ: 159.5, 138.2 (CqAr); 134.3, 129.5, 129.0 (CHAr); 128.7 (CqAr); 128.3,
128.1, 127.7, 127.6, 114.0 (CH<sub>arom</sub>); 85.6 (C-1); 80.3, 75.8 (C-3, C-4); 74.9, 72.2 (PhCH<sub>2</sub>); 69.4 (C-5); 60.8 (C-2), 55.3 (OCH<sub>3</sub>); 16.5 (C-6). IR (thin film) ν: 2868, 2104, 1612, 1512, 1246, 1099, 1063, 1034. HRMS: [M+H]<sup>+</sup> calculated for C<sub>25</sub>H<sub>30</sub>N<sub>4</sub>O<sub>4</sub>Se 540.13960; found 540.13940.

*Phenyl 2-azido-4-O-benzyl-2-deoxy-1-seleno-α-L-fucopyranoside (14)*

![Formula](attachment:formula.png)

To a stirred solution of 13 (1.56 g, 2.9 mmol, 1.0 eq.) and Et<sub>3</sub>SiH (0.73 mL, 8.7 mmol, 3.0 eq.) in CH<sub>2</sub>Cl<sub>2</sub> (15 mL, 0.2 M) was added a solution of HCl (0.25 mL of an 37%, w/v in water) in HFIP (15 mL). After 1 minute, the mixture was poured in a solution of NaHCO<sub>3</sub> (sat.,aq.). After separation of the layers, the aqueous phase was extracted (CH<sub>2</sub>Cl<sub>2</sub>, 1x), the combined organic phases were washed (brine, 1x), dried over MgSO<sub>4</sub>, filtered and concentrated *in vacuo*. After column chromatography (toluene/EtOAc, 1:0 → 9:1), the title compound was obtained as an oil, in 64% yield (0.78 g, 1.9 mmol). <sup>1</sup>H NMR (400 MHz) δ: 7.58-7.56 (m, 2H, CH<sub>arom</sub>); 7.38-7.25 (m, 8H, CH<sub>arom</sub>); 5.91 (d, 1H, J = 5.2 Hz, H-1); 4.81 (d, 1H, J = 11.6 Hz, PhCH<sub>2</sub>); 4.72 (d, 1H, J = 11.6 Hz, PhCH<sub>2</sub>HF); 4.33 (q, 1H, J = 6.4 Hz, H-5); 4.02 (dd, 1H, J = 5.2 Hz, 10.2 Hz, H-2); 3.85-3.79 (m, 1H, H-3); 3.69 (d, 1H, J = 2.8 Hz, H-4); 2.26 (d, 1H, J = 8.8 Hz, 3-<sub>O</sub>H); 1.25 (d, 3H, J = 6.8 Hz, H-6). <sup>13</sup>C-APT NMR (100 MHz) δ: 137.7 (C<sub>qarom</sub>); 134.3, 129.1, 128.7, 128.2, 128.1, 127.7 (CH<sub>arom</sub>); 85.2 (C-1); 79.3 (C-4); 71.9 (C-3); 69.3 (C-5); 62.5 (C-2); 16.6 (C-6). IR (thin film) ν: 3468, 2882, 2106, 1263, 1094, 1057, 1022. HRMS: [M -N<sub>2</sub>+H]<sup>+</sup> calculated for C<sub>19</sub>H<sub>22</sub>NO<sub>3</sub>: 392.07594; found 392.07593.

*Phenyl 2-azido-3-O-benzoyl-4-O-benzyl-2-deoxy-1-seleno-α-L-fucopyranoside (4)*

![Formula](attachment:formula.png)

To a stirred solution of 14 (0.21 g, 0.5 mmol, 1.0 eq.) in CH<sub>2</sub>Cl<sub>2</sub>/pyridine (1.6 mL, 0.3 M, 1:1 v/v) were added BzCl (0.12 mL, 1.0 mmol, 2 eq.) and DMAP (6 mg, 0.05 mmol, 0.1 eq.) at 0 °C. After TLC analysis indicated complete conversion of the starting material (typically, the reaction mixture was left overnight), the reaction was quenched by addition of MeOH. The mixture was diluted with CH<sub>2</sub>Cl<sub>2</sub>, washed with Cu<sub>2</sub>SO<sub>4</sub>.5H<sub>2</sub>O (in H<sub>2</sub>O, 10% w/v, 2x), water (1x) and brine (1x), dried over MgSO<sub>4</sub>, filtered and concentrated *in vacuo*. Purification by column chromatography (PE/Et<sub>2</sub>O, 1:0 → 9:1) furnished the title compound in 96% yield (0.25 g, 0.48 mmol). <sup>1</sup>H NMR (400 MHz)
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors

MHz) δ: 8.09 (d, 2H, J = 7.6 Hz, CH$_{arom}$); 7.63-7.58 (m, 3H, CH$_{arom}$); 7.48 (t, 2H, J = 7.6 Hz, CH$_{arom}$); 7.41-7.23 (m, 8H, CH$_{arom}$); 6.01 (d, 1H, J= 5.2 Hz, H-1); 5.29 (dd, 1H, J= 2.8 Hz, 11.0 Hz, H-3); 4.67 (d, 1H, J = 11.2 Hz, PhCHH); 4.58 (dd, 1H, J = 5.2 Hz, 11.2 Hz, H-2); 4.53 (d, 1H, J = 11.6 Hz, PhCHH); 4.43 (q, 1H, J = 6.4 Hz, H-5); 4.01 (d, 1H, J = 2.0 Hz, H-4); 1.17 (d, 3H, J = 6.4 Hz, H-6).

$^{13}$C-APT NMR (100 MHz) δ: 165.7 (CO$_{as}$); 137.4 (C$_{qarom}$); 134.5, 133.7, 129.9, 129.1 (CH$_{arom}$); 129.0 (C$_{qarom}$); 128.6 (CH$_{arom}$); 128.4 (C$_{qarom}$); 128.3, 128.1, 127.9, 127.8 (CH$_{arom}$); 84.9 (C-1); 76.6 (C-4); 75.6 (PhCH$_2$); 75.1 (C-3); 69.1 (C-5); 59.6 (C-2); 16.3 (C-6). IR (thin film) ν: 2936, 2108, 1722, 1267, 1107, 1086, 1070. HRMS: [M+Na]$^+$ calculated for C$_{26}$H$_{34}$N$_3$O$_3$SeNa: 546.09025; found 546.09021.

**Phenyl 2-azido-4-O-benzyl-2-deoxy-3-O-(tert-butyl(dimethyl)silyl)-1-seleno-α-L-fucopyranoside (6)**

A 50 mL, three-necked flask was equipped with a septum, a gas inlet and a Liebig condenser fitted with a drying tube. Under a flow of N$_2$ gas, the flask was charged with a solution of 14 (0.63 g, 1.5 mmol, 1.0 eq.) in pyridine (7.5 mL, 0.2 M). At 0 °C, added was DMAP (4 mg, 0.3 mmol, 0.2 eq.) followed by TBSOTf (0.69 mL, 3.0 mmol, 2.0 eq., in a dropwise fashion). The mixture was heated to 70 °C and stirred for 16 hours, after which TLC analysis (PE/Et$_2$O, 19:1 v/v) showed complete conversion of the starting material. The reaction was cooled to rT, quenched with MeOH and the mixture diluted with EtOAc. The mixture was washed with 10% aq. CuSO$_4$ solution (2x), H$_2$O and brine, dried over MgSO$_4$, filtered and concentrated *in vacuo*. Purification by column chromatography (PE/Et$_2$O, 1:0 → 19:1 v/v) furnished the title compound as a light-yellow oil in 92% yield (0.73 g, 1.38 mmol). $^1$H NMR (400 MHz) δ: 7.57-7.55 (m, 2H, CH$_{arom}$); 7.39-7.26 (m, 8H, CH$_{arom}$); 5.96 (d, 1H, J = 4.8 Hz, H-1); 5.06 (d, 1H, J = 11.2 Hz, PhCHH); 4.59 (d, 1H, J = 11.2 Hz, PhCHH); 4.27 (q, 1H, J = 6.4 Hz, H-5); 4.22 (dd, 1H, J = 5.2 Hz, 10.0 Hz, H-2); 3.88 (dd, 1H, J = 2.4 Hz, 10.0 Hz, H-3); 3.53 (bs, 1H, H-4); 1.15 (d, 3H, J = 6.4 Hz, H-6); 0.99 (s, 9H, (CH$_3$)$_3$CSi); 0.25, 0.22 (s, 3H, CH$_3$Si). $^{13}$C-APT NMR (100 MHz) δ: 138.5 (C$_{qarom}$); 134.3, 129.0, 128.3, 127.8, 127.7, 127.6 (CH$_{arom}$); 85.6 (C-1); 80.1 (C-4); 75.6 (PhCH$_2$); 74.2 (C-3); 69.4 (C-5); 62.9 (C-2); 26.0 ((CH$_3$)$_3$CSi); 16.5 (C-6). IR (thin film) ν: 2953, 2930, 2886, 2857, 2106, 1472, 1260, 1111, 1080, 1062, 1042, 1022. HRMS: [M+H]$^+$ calculated for C$_{26}$H$_{36}$N$_3$O$_3$SeSi: 534.16857; found 534.16882.
General procedure for generation of glycosyl triflates and oxosulfonium triflates

\[
\begin{align*}
\text{SePh} & \quad \text{Ph}_2\text{SO}, \text{CD}_2\text{Cl}_2; \\
& \quad \text{Tf}_2\text{O}, -80 ^\circ \text{C} \\
\end{align*}
\]

A mixture of glycosyl donor (0.038 mmol, 1.0 eq.) and Ph\(_2\)SO (10 mg, 0.049 mmol, 1.3 eq.; 15 mg, 0.076 mmol, 2.0 eq.; or 31 mg, 0.152 mmol, 4.0 eq.) were dried by co-evaporation with toluene (3x), followed by three vacuum/argon purges. The mixture was dissolved in CD\(_2\)Cl\(_2\) (0.75 mL, 0.05 M) and transferred to a dry-NMR tube, which was subsequently capped with a septum. The tube was placed in the probe of a NMR magnet and cooled to -80 °C, after which a \(^1\)H NMR spectrum was recorded. The tube was then removed from the magnet and placed in an acetone/N\(_2\) (l) bath (temperature ≤ -80 °C). Tf\(_2\)O (8 μL, 0.049 mmol, 1.3 eq.) was added with a microliter syringe and, after rapid mixing and re-cooling, the tube was placed back in the NMR instrument. A \(^1\)H NMR spectrum was recorded, which revealed the formation of reactive intermediate(s). After further characterization (\(^{13}\)C-APT NMR, HH-COSY and HSQC) the temperature of the sample was increased by increments of 10 °C until decomposition of the intermediate(s) was observed.

General procedure for glycosylations of 2-azido-2-deoxy-\(\alpha\)-fucosyl donors by pre-activation.

\[
\begin{align*}
\text{SePh} & \quad \text{Ph}_2\text{SO}, \text{TTBP, 3A MS, CH}_2\text{Cl}_2; \\
& \quad \text{Tf}_2\text{O}, -80 \text{ to } -60 ^\circ \text{C;} \\
\end{align*}
\]

To a mixture of donor (0.1 mmol, 1.0 eq.), Ph\(_2\)SO (26 mg, 0.13 mmol, 1.3 eq.) and TTBP (62 mg, 0.25 mmol, 2.5 eq.) in dry CH\(_2\)Cl\(_2\) (2 mL, 0.05 M) were added flame-dried 3Å molecular sieves. The mixture was subsequently stirred for 30 minutes before being cooled to -80 °C. At this temperature, Tf\(_2\)O (22 μL, 0.13 mmol, 1.3 eq.) was added via syringe, and the temperature was raised to -60 °C over the course of ~30 minutes. After re-cooling to -80 °C, the acceptor (0.2 mmol, 2.0 eq., 0.4 mL of a 0.5 M stock solution in CH\(_2\)Cl\(_2\)) was added at -80 °C and the reaction mixture was allowed to warm to -40 °C, after which the reaction was quenched by addition of NEt\(_3\) (0.1 mL) and subsequently diluted with CH\(_2\)Cl\(_2\). The mixture was filtered through a small bed of celite, the residue washed with CH\(_2\)Cl\(_2\) and the filtrate was washed once with brine, dried over MgSO\(_4\), filtered and concentrated in vacuo. Purification by ordinary column chromatography and/or size-exclusion chromatography afforded the corresponding O-glycoside(s).
Ethyl 2-azido-3,4-di-O-benzyl-2-deoxy-α/β-L-fucopyranoside (A1)

The title compounds (α/β 1:1) were obtained after column chromatography (hexane/EtOAc, 1:0 → 9:1) in 88% yield (35 mg, 0.088 mmol). 1H NMR (400 MHz) δ: 7.43-7.25 (m, 18H, CH arom); 4.95-4.92 (m, 1.8H, PhCH₂α, PhCH₂β); 4.90 (d, 0.8H, J = 4.0 Hz, H-1α); 4.74-4.60 (m, 5.4H, PhCH₂α, PhCH₂β); 4.18 (d, 1H, J = 8.0 Hz, H-1β); 3.99-3.78 (m, 4.2H, H-2α, H-2β, H-3α, H-5α, CHCH₃α); 3.75-3.67 (m, 1.8H, H-4β, CHCH₃β); 3.60-3.50 (m, 2.8H, H-4β, CHCH₃α, CHCH₃β); 3.41 (q, 1H, J = 6.4 Hz, H-5β); 3.30 (dd, 1H, J = 2.8 Hz, 10.4 Hz, H-3β); 1.28-1.16 (m, 10.8H, H-6α, H-6β, CH₂CH₃α, CH₂CH₃β). 13C-APT NMR (100 MHz) δ: 138.3, 137.7 (C q arom); 128.5, 128.5, 128.4, 128.3, 128.2, 127.9, 127.8, 127.7, 127.6 (CH arom); 120.2 (C-1β); 97.9 (C-1α); 81.1 (C-3β); 78.0 (C-3α); 76.3 (C-4α); 74.9 (4-β); 74.9, 74.6, 72.6, 72.4 (Ph CH₂); 70.5 (C-5β); 66.5 (C-5α); 65.3 (CH₂CH₃α); 63.7 (CH₂CH₃β); 63.0 (C-2β); 59.6 (C-2α); 16.9, 16.7 (C-6); 15.0, 15.0 (CH₂CH₃). IR (thin film) ν: 2893, 2106, 1454, 1356, 1099, 1063. HRMS: [M+NH₄]+ calculated for CₓHₓNₓOₓ: 415.23398; found 415.23393.

Ethyl 2-azido-3,4-di-O-benzoyl-2-deoxy-α/β-L-fucopyranoside (A2)

The title compounds (α/β 1:4) were obtained after column chromatography (hexane/EtOAc, 1:0 → 4:1 v/v), in 39% yield (25 mg, 0.059 mmol). 1H NMR (400 MHz) δ: 8.09-8.03 (m, 10H, CH arom); 7.89-7.86 (m, 9H, CH arom); 7.64-7.59 (m, 6H, CH arom); 7.53-7.46 (m, 17H, CH arom); 7.35-7.31 (m, 10H, CH arom); 5.78 (dd, 1H, J = 3.2 Hz, 10.8 Hz, H-3α); 5.71 (dd, 1H, J = 1.2 Hz, 3.2 Hz, H-4α); 5.59 (dd, 4H, J = 0.8 Hz, 3.2 Hz, H-4β); 5.17 (dd, 4H, J = 3.6 Hz, 10.8 Hz, H-3β); 5.13 (d, 1H, J = 3.6 Hz, H-1α); 4.51 (d, 4H, J = 8.0 Hz, H-1β); 4.37 (q, 1H, J = 6.4 Hz, H-5α); 4.10 (dq, 4H, J = 7.2 Hz, 9.6 Hz, CHCH₃β); 3.98-3.90 (m, 8H, H-2β, H-5β); 3.88-3.84 (m, 2H, H-2α, CHCH₃α); 3.76-3.63 (m, 6H, CHCH₃α, CHCH₃β); 1.37-1.21 (m, 30H, H-6α, H-6β, CH₂CH₃α, CH₂CH₃β). 13C-APT NMR (100 MHz) δ: 165.8, 165.8, 165.4 (CO₂H₂); 133.4, 133.4, 133.3, 133.2, 129.9, 129.7 (CH arom); 129.2, 129.1 (C q arom); 128.5, 128.5, 128.3, 128.3 (CH arom); 102.2 (C-1β); 98.1 (C-1α); 72.0 (C-3β); 71.4 (C-4α); 70.3 (C-4β); 69.5 (C-5β); 69.3 (C-3α); 66.2 (CH₂CH₃β); 65.1 (C-5α); 64.3 (CH₂CH₃α); 61.2 (C-2β); 57.9 (C-2α); 16.3 (C-6β); 16.1 (C-6α); 15.1 (CH₂CH₃β); 15.0 (CH₂CH₃α). IR (thin film) ν: 1980,
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2927, 2110, 1724, 1450, 1261, 1175, 1109, 1094, 1067, 1026. HRMS: [M+Na]+ calculated for \( \text{C}_{22}\text{H}_{23}\text{N}_3\text{O}_5\text{Na} \): 448.14791; found 448.14784.

**Ethyl 2-azido-4-O-benzoyl-3-O-benzyl-2-deoxy-α/β-L-fucopyranoside (A3)**

![Structure of A3](image)

The title compounds (α/β 1:3) were obtained after column chromatography (hexane/Et₂O, 1:0 → 4:1 v/v) in 61% yield (25 mg, 0.061 mmol). \(^1\)H NMR (400 MHz) δ: 8.15-8.07 (m, 8H, \( \text{C}_{6}\text{H}_{4}\text{arom} \)); 7.60-7.56 (m, 4H, \( \text{C}_{6}\text{H}_{4}\text{arom} \)); 7.48-7.44 (m, 8H, \( \text{C}_{6}\text{H}_{4}\text{arom} \)); 7.36-7.24 (m, 20H, \( \text{C}_{6}\text{H}_{4}\text{arom} \)); 5.68 (d, 1H, \( J = 2.4 \text{ Hz} \), H-4α); 5.54 (dd, 3H, \( J = 0.8 \text{ Hz}, 3.2 \text{ Hz}, \text{H-4β} \)); 4.98 (d, 1H, \( J = 3.6 \text{ Hz}, \text{H-1α} \)); 4.83 (d, 1H, \( J = 10.8 \text{ Hz}, \text{PhCH}_\text{Hα} \)); 4.79 (d, 3H, \( J = 11.6 \text{ Hz}, \text{PhCH}_\text{Hβ} \)); 4.56-4.53 (m, 4H, \( \text{PhCH}_\text{Hα}, \text{PhCH}_\text{Hβ} \)); 4.28 (d, 4H, \( J = 8.0 \text{ Hz}, \text{H-1β} \)); 4.18 (q, 1H, \( J = 6.8 \text{ Hz}, \text{H-5α} \)); 4.11 (dd, 1H, \( J = 3.2 \text{ Hz}, 10.4 \text{ Hz}, \text{H-3α} \)); 4.06-3.99 (m, 3H, \( \text{CH}_3\text{CH}_\text{β} \)); 3.78-3.60 (m, 11H, H-2α, H-2β, H-5β, \( \text{CH}_2\text{CH}_\text{α}, \text{CH}_2\text{CH}_\text{β} \)); 3.45 (dd, 3H, \( J = 3.2 \text{ Hz}, 10.4 \text{ Hz}, \text{H-3β} \)); 1.59-1.26 (m, 21H, H-6β, \( \text{CH}_2\text{CH}_\text{α}, \text{CH}_2\text{CH}_\text{β} \)); 1.22 (d, 3H, \( J = 6.8 \text{ Hz}, \text{H-6α} \)). \(^{13}\)C NMR (100 MHz) δ: 166.2 (\( \text{CD}_2\text{OD} \)); 137.2, 137.1 (\( \text{C}_\text{arom} \)); 133.3, 133.2, 130.0, 129.8 (\( \text{CH}_\text{arom} \)); 129.4 (\( \text{C}_\text{arom} \)); 128.5, 128.4, 128.4, 128.4, 126.4, 117.5, 117.5, 1111, 1065, 1026. HRMS: [M+H]+ calculated for \( \text{C}_{22}\text{H}_{26}\text{N}_3\text{O}_5 \): 412.18670 found 412.18702.

**Ethyl 2-azido-3-O-benzoyl-4-O-benzyl-2-deoxy-α/β-L-fucopyranoside (A4)**

![Structure of A4](image)

The title compounds (α/β 2:5) were obtained after column chromatography (hexane/Et₂O 1:0 → 9:1), in 58% yield (24 mg, 0.058 mmol). \(^1\)H NMR (400 MHz) δ: 8.10-8.06 (m, 14H, \( \text{C}_{6}\text{H}_{4}\text{arom} \)); 7.62-7.58 (m, 7H, \( \text{C}_{6}\text{H}_{4}\text{arom} \)); 7.49-7.45 (m, 14H, \( \text{C}_{6}\text{H}_{4}\text{arom} \)); 7.26-7.19 (m, 35H, \( \text{C}_{6}\text{H}_{4}\text{arom} \)); 5.57 (dd, 2H, \( J = 3.0 \text{ Hz}, 11.0 \text{ Hz}, \text{H-3α} \)); 5.00 (d, 2H, \( J = 3.6 \text{ Hz}, \text{H-1α} \)); 4.95 (dd, 5H, \( J = 3.0 \text{ Hz}, 11.0 \text{ Hz}, \text{H-3β} \)); 4.72-4.68 (m, 7H, \( \text{PhCH}_\text{Hα}, \text{PhCH}_\text{Hβ} \)); 4.57-4.52 (m, 7H, \( \text{PhCH}_\text{Hα}, \text{PhCH}_\text{Hβ} \)); 4.37 (d, 5H, \( J = 8.0 \text{ Hz}, \text{H-1β} \)); 4.11 (q, 2H, \( J = 6.8 \text{ Hz}, \text{H-5α} \)); 4.05-3.94 (m, 14H, H-2α, H-2β, H-4α, \( \text{CH}_2\text{CH}_\text{β} \)); 3.82-3.74 (m,
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7H, H-4β, CH₂CH₃α); 3.68-3.56 (m, 12H, H-5β, CH₃CH₅α, CH₃CH₅β); 1.31-1.20 (m, 42H, H-6α, H-6β, CH₂CH₅α, CH₂CH₅β). ¹³C-APT NMR (100 MHz) δ: 165.9 (CO Bz); 137.6, 137.5 (C₆H₅); 133.5, 133.5, 129.9 (CH₆H₅); 129.2 (C₆H₅); 128.5, 128.3, 128.2, 128.1, 127.8, 127.8, 127.6 (CH₆H₅); 101.9 (C-1β); 98.0 (C-1α); 77.4 (C-4α); 76.0 (C-4β); 75.5 (PhCH₂α); 75.4 (PhCH₂β); 75.0 (C-3β); 72.3 (C-3α); 70.5 (C-5β); 66.2 (CH₂CH₃β); 63.9 (CH₂CH₃α); 61.2 (C-2β); 64.0, 16.1, 15.0, 15.0 (CH₂CH₃β, C-6α, C-6β). IR (thin film) ν: 2978, 2932, 2108, 1721, 1452, 1265, 1028, 1012, 762.

Ethyl 2-azido-2-deoxy-3,4-di-O-(tert-butyldimethylsilyl)-α/β-l-fucopyranoside (A5)

The title compounds (α/β 2:5) were obtained after column chromatography (hexane/Et₂O, 1:0 → 19:1), along with a minor amount of inseparable, hydrolyzed donor, in 63% yield (28 mg, 0.063 mmol). ¹H NMR (400 MHz) δ: 4.91 (d, 2H, J = 3.6 Hz, H-1α); 4.19 (d, 5H, J = 8.0 Hz, H-1β); 4.01-3.95 (m, 7H, H-3α, OCH₃CH₃β); 3.88 (q, 2H, J = 6.4 Hz, H-5α); 3.73-3.70 (m, 6H, H-2α, H-4α, OCH₃CH₃α); 3.62-3.52 (m, 17H, H-2β, H-4β, OCH₃CH₃α, OCH₃CH₃β); 3.45 (q, 5H, J = 6.4 Hz, H-5β); 3.35 (dd, 5H, J = 2.4 Hz, 10.4 Hz, H-3β); 1.29-1.18 (m, 42H, H-6α, H-6β, CH₂CH₃α, CH₂CH₃β); 0.96-0.93 (m, 126H, (CH₃)₃CSiα, (CH₃)₃CSiβ); 0.19-0.09 (m, 84H, CH₅Siα, CH₅Siβ). ¹³C-APT NMR (100 MHz) δ: 102.5 (C-1β); 97.7 (C-1α); 75.2 (C-4α); 74.5 (C-3β); 74.0 (C-4β); 71.3 (C-3α); 71.2 (C-5β); 67.7 (C-5α); 65.5 (OCH₂CH₂β); 63.8 (C-2β); 63.4 (OCH₂CH₂α); 61.1 (C-2α); 26.3, 26.2, 26.1 ((CH₃)₃CSi); 18.6, 18.5 (C₆Si); 17.6, 17.3 (OCH₂CH₂); 15.1, 15.0 (C-6α, C-6β); -3.5, -3.6, -4.2, -4.4 (CH₃Si). IR (thin film) ν: 2928, 2857, 2112, 1252, 1117, 1069. HRMS: [M+NH₄]⁺ calculated for C₂₂H₂₅N₄O₅S₂: 463.31304; found 463.31293.

Ethyl 2-azido-4-O-benzyl-2-deoxy-3-O-(tert-butyldimethylsilyl)-α/β-l-fucopyranoside (A6)

The title products (α/β 1:1) were obtained after column chromatography (hexane/Et₂O, 1:0 → 19:1 v/v) in 81% yield (34 mg, 0.081 mmol). ¹H NMR (400 MHz) δ: 7.39-7.26 (m, 10H, C₆H₅); 5.05-5.02 (m, 2H, PhCH₂α, PhCH₂β); 4.91 (d, 1H, J = 3.6 Hz, H-1α); 4.61-4.56 (m, 2H, PhCH₂α, PhCH₂β); 4.19 (d, 1H, J = 8.0 Hz, H-1β); 4.12 (dd, 1H, J = 2.8 Hz, 10.0 Hz, H-3α); 3.98-3.93 (m, 2H,
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H-5α, OCH2CH3); 3.74-3.50 (m, 8H, H-2α, H-2β, H-3β, H-4α, H-5β, OCH2CH3, 2x OCH2CH3); 3.37 (d, 1H, J = 2.4 Hz, H-4β); 1.27-1.19 (m, 12H, H-6α, H-6β, OCH2CH2α, OCH2CH2β); 0.98, 0.96 (s, 9H, (CH3)3C); 0.24 (s, 3H, CH3Si); 0.18 (m, 6H, CH3Si); 0.15 (s, 3H, CH3Si). 13C-APT NMR (100 MHz) δ: 138.6, 138.6 (Cqarom); 128.3, 128.1, 128.1, 127.9, 127.6, 127.5 (CHarom); 102.1 (C-1β); 97.8 (C-1α); 80.9 (C-4α), 79.2 (C-4β); 75.6, 75.3 (PhCH2); 74.9 (C-3β or C-5β); 71.5 (C-3α); 70.3 (C-3β or C-5β); 66.5 (C-5α); 65.4 (OCH2CH3); 64.6 (C-2β); 63.6 (OCH2CH3); 61.5 (C-2α); 25.9, 25.9 ((CH3)3C); 18.2, 18.1 (C6Si); 16.8, 16.7 (C-6α, C-6β); 15.1, 15.0 (OCH2CH3α, OCH2CH3β); -4.0, -4.3, -4.7, -5.0 (CH3Si). IR (thin film) ν: 2930, 2876, 1726, 1358, 1109, 1062, 1047. HRMS: [M+NH4]+ calculated for C22H39N4O4Si; 439.27351; found 439.27319

2-fluoroethyl 2-azido-3,4-di-O-benzyl-2-deoxy-α/β-L-fucopyranoside (B1)

The title products (α/β 1:1) were obtained after column chromatography (hexane/EtOAc, 1:0 → 4:1), in 72% yield (30 mg, 0.072 mmol). 1H NMR (400 MHz) δ: 7.66-7.63 (m, 2H, CHarom); 7.46-7.25 (m, 18H, CHarom); 4.95-4.91 (m, 3H, H-1α, 2x PhCH); 4.74-4.50 (m, CH3Fα, CH3Fβ, 2x PhCH); 4x PhCH2F; 4.26 (d, 1H, J = 8.0 Hz, H-1β); 4.02-3.73 (m, 9H, H-2α, H-2β, H-3α; H-4α, H-5α, CH2CH2Fα, CH2CH2Fβ); 3.54 (d, 1H, J = 2.4 Hz, H-4β); 3.42 (q, 1H, J = 6.4 Hz, H-5β); 3.31 (dd, 1H, J = 2.8 Hz, 10.4 Hz, H-3β); 1.20-1.17 (m, 6H, H-6α, H-6β). 13C-APT NMR (100 MHz) δ: 138.2, 137.6 (Cqarom); 131.0, 129.9, 128.5, 128.5, 128.4, 128.3, 128.2, 127.9, 127.8, 127.7, 127.7, 124.7 (CHarom); 102.3 (C-1β); 98.4 (C-1α); 82.7 (d, J = 168 Hz, CH2F); 82.5 (d, J = 168 Hz, CH2F); 80.9 (C-3β); 77.8 (C-3α); 76.1 (C-4α); 74.9 (PhCH2); 74.8 (C-4β); 72.7, 72.4 (PhCH2); 70.6 (C-5β); 68.3 (d, 20 Hz, CH2CH2F); 67.1 (d, 20 Hz, CH2CH2F); 66.7 (C-5α); 62.9 (C-2β); 59.5 (C-2α); 16.8, 16.7 (C-6α, C-6β). IR (thin film) ν: 2876, 2108, 1726, 1358, 1109, 1062, 1045. HRMS: [M+NH4]+ calculated for C22H38FN4O4: 433.22456; found 433.22418.

2-fluoroethyl 2-azido-3,4-di-O-benzyl-2-deoxy-α/β-L-fucopyranoside (B2)

The title compounds (α/β 1:2) were obtained after column chromatography (hexane/EtOAc, 1:0 → 4:1) in 34% yield (15 mg, 0.034 mmol). 1H NMR (400 MHz) δ: 8.08-8.03 (m, 6H, CHarom); 7.89-
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors

7.86 (m, 6H, \(CH_{2}\text{arom}\)); 7.63-7.60 (m, 3H, \(CH_{2}\text{arom}\)); 7.53-7.46 (m, 9H, \(CH_{2}\text{arom}\)); 7.35-7.31 (m, 6H, \(CH_{2}\text{arom}\)); 5.78 (dd, 1H, \(J = 3.2\) Hz, H-3α); 5.72 (d, 1H, \(J = 3.2\) Hz, H-4α); 5.59 (d, 2H, \(J = 3.2\) Hz, H-4β); 5.19-5.16 (m, 3H, H-1α, H-3β); 4.77-4.60 (m, 6H, \(CH_{2}\text{Fe}, CH_{2}\text{Fβ}, H-1β\)); 4.58 (d, 2H, \(J = 8.4\) Hz, H-1β); 4.42 (q, 1H, \(J = 6.8\) Hz, H-5α); 4.25-3.89 (m, 11H, H-2α, H-2β, H-5β, \(CH_{2}\text{CH}_{2}\text{Fe}, CH_{2}\text{CH}_{2}\text{Fβ}\)); 1.31 (d, 6H, \(J = 6.4\) Hz, H-6β); 1.25 (d, 3H, \(J = 6.4\) Hz, H-6α). \(^{13}\)C-APT NMR (100 MHz) \(\delta\): 165.8, 165.4 (\(CO_{\text{Bz}}\)); 133.5, 133.4, 133.3, 133.3, 129.9, 129.8 (\(CH_{2}\text{arom}\)); 129.3, 129.2, 129.0 (\(C_{\text{arom}}\)); 128.6, 128.3 (\(CH_{\text{arom}}\)); 102.5 (C-1β); 98.6 (C-1α); 82.6 (d, \(J = 169\) Hz, \(CH_{2}\text{CH}_{2}\text{Fβ}\)); 82.4 (d, \(J = 170\) Hz, \(CH_{2}\text{CH}_{2}\text{Fβ}\)); 72.0 (C-3β); 71.3 (C-4α); 70.2 (C-4β); 69.7 (C-5β); 69.2 (C-3α); 69.1 (d, \(J = 21\) Hz, \(CH_{2}\text{CH}_{2}\text{Fβ}\)); 67.5 (d, \(J = 20\) Hz, \(CH_{2}\text{CH}_{2}\text{Fβ}\)); 65.4 (C-5α); 61.3 (C-2β); 58.0 (C-2α); 16.3 (C-6β); 16.1 (C-6α). IR (thin film) \(\nu\): 2984, 2924, 2110, 1721, 1450, 1260, 1169, 1107, 1094, 1067, 1026. HRMS: \([M+Na]^+\) calculated for \(C_{22}H_{22}FNO_5\): 466.13848; found 466.13840.

2-fluoroethyl 2-azido-4-O-benzoyl-3-O-benzyl-2-deoxy-\(\alpha/\beta\)-L-fucopyranoside (B3)

The products (\(\alpha/\beta\) 1:1) were obtained after column chromatography (hexane/EtOAc, 1:0 → 9:1) and size-exclusion chromatography (CH\(_2\)Cl\(_2\)/MeOH, 1:1 v/v) in 56% yield (24 mg, 0.056 mmol), accompanied by a small amount of inseparable, hydrolyzed donor. \(^1\)H NMR (400 MHz) \(\delta\): 8.14-8.07 (m, 4H, \(CH_{2}\text{arom}\)); 7.60-7.56 (m, 2H, \(CH_{2}\text{arom}\)); 7.49-4.44 (m, 4H, \(CH_{2}\text{arom}\)); 7.35-7.25 (m, 10H, \(CH_{2}\text{arom}\)); 5.70 (d, 1H, \(J = 2.8\) Hz, H-4α); 5.55 (d, 1H, \(J = 3.2\) Hz, H-4β); 5.02 (d, 1H, \(J = 3.6\) Hz, H-1α); 4.85-4.53 (m, 8H, \(CH_{2}\text{Fe}, CH_{2}\text{Fβ}, PhCH_{2}\alpha, PhCH_{2}\beta\)); 4.36 (d, 1H, \(J = 8.0\) Hz, H-1β); 4.24 (q, 1H, \(J = 6.4\) Hz, H-5α); 4.15-3.71 (m, 8H, H-2α, H-2β, H-3α, H-5β, \(CH_{2}\text{CH}_{2}\text{Fe}, CH_{2}\text{CH}_{2}\text{Fβ}\)); 3.47 (dd, 1H, \(J = 3.2\) Hz, 10.2 Hz, H-3β); 1.28-1.21 (m, 6H, H-6α, H-6β). \(^{13}\)C-APT NMR (100 MHz) \(\delta\): 166.2, 166.1 (\(CO_{\text{Bz}}\)); 137.1, 137.0 (\(C_{\text{arom}}\)); 133.4, 133.3, 130.2, 130.0, 129.8, 129.6 (\(CH_{2}\text{arom}\)); 129.4 (\(C_{\text{arom}}\)); 128.5, 128.4, 128.2, 128.0, 127.9, 127.8 (\(CH_{2}\text{arom}\)); 102.3 (C-1β); 98.4 (C-1α); 82.7 (d, \(J = 169\) Hz, \(CH_{2}\text{Fβ}\)); 82.5 (d, \(J = 170\) Hz, \(CH_{2}\text{Fe}\)); 77.5 (C-3β); 74.3 (C-3α); 71.6 (PhCH_{2}\beta); 71.5 (PhCH_{2}\alpha); 69.8 (C-4α); 69.6 (C-5β); 68.8 (d, \(J = 20\) Hz, \(CH_{2}\text{CH}_{2}\text{Fβ}\)); 68.8 (C-4β); 67.4 (d, \(J = 20\) Hz, \(CH_{2}\text{CH}_{2}\text{Fe}\)); 65.4 (C-5α); 62.6 (C-2β); 59.2 (C-2α); 16.5, 16.3 (C-6α, C-6β). IR (thin film) \(\nu\): 2926, 2110, 1721, 1452, 1267, 1169, 1111, 1067, 1026. HRMS: \([M-N_2+H]^+\) calculated for \(C_{22}H_{23}FNO_6\): 402.17113; found 402.17108.
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2-fluoroethyl 2-azido-3-O-benzoyl-4-O-benzyl-2-deoxy-α/β-l-fucopyranoside (B4)

\[ \text{O} \quad \begin{array}{c} \text{N} \end{array} \]

The products (α/β 2:3) were obtained after column chromatography (hexane/EtOAc, 1:0 → 9:1) and size-exclusion chromatography (\( \text{CH}_2\text{Cl}_2/\text{MeOH}, 1:1 \)) in 60% yield (26 mg, 0.060 mmol). ³¹H NMR (400 MHz) δ: 8.10-8.06 (m, 10H, CH\text{arom}); 7.62-7.58 (m, 5H, CH\text{arom}); 7.49-7.45 (m, 10H, CH\text{arom}); 7.26-7.20 (m, 25H, CH\text{arom}); 5.58 (dd, 2H, \( J = 2.8 \) Hz, H-3α); 5.05 (d, 2H, \( J = 3.6 \) Hz, H-1α); 4.95 (dd, 3H, \( J = 3.2 \) Hz, H-3β); 4.73-4.52 (m, 20H, CH\text{CH}_2\text{F}, PhCH\text{F}); 4.43 (d, 3H, \( J = 8.0 \) Hz, H-1β); 4.17-3.78 (m, 22H, H-2α, H-2β, H-4α, H-4β, H-5α, CH\text{CH}_2\text{F}); 3.67 (q, 3H, \( J = 6.4 \) Hz, H-5β); 1.26-1.21 (m, 15H, H-6α, H-6β). ¹³C-APT NMR (100 MHz) δ: 165.8 (C\text{Oe}); 137.5, 137.4 (C\text{arom}); 133.6, 133.5, 129.9 (CH\text{arom}); 129.3, 129.1 (C\text{arom}); 128.6, 128.3, 128.1, 127.9, 127.9 (CH\text{arom}); 102.3 (C-1β); 98.5 (C-1α); 82.6 (d, \( J = 168 \) Hz, CH\text{CH}_2\text{F}); 82.4 (d, \( J = 169 \) Hz, CH\text{CH}_2\text{F}); 77.2 (C-4α); 75.9 (C-4β); 75.6 (PhCH\text{F}); 75.4 (PhCH\text{F}); 74.9 (C-3β); 72.2 (C-3α); 70.6 (C-5β); 68.6 (d, \( J = 21 \) Hz, CH\text{CH}_2\text{F}); 67.3 (d, \( J = 20 \) Hz, CH\text{CH}_2\text{F}); 66.5 (C-5α); 61.2 (C-2β); 58.0 (C-2α); 16.6 (C-6β). IR (thin film) ν: 2934, 2110, 1721, 1452, 1267, 1171, 1096, 1069, 1026. HRMS: [M+NH₄]⁺ calculated for C\text{2}₂\text{H}_\text{2}\text{F}_\text{N}_\text{4}O₂: 447.20382; found 447.20380.

2-fluoroethyl 2-azido-2-deoxy-3,4-di-O-(tert-butyldimethylsilyl)-α/β-l-fucopyranoside (B5)

\[ \text{O} \quad \begin{array}{c} \text{N} \end{array} \]

The products (α/β 2:3) were obtained after column chromatography (hexane/Et₂O, 1:0 → 9:1) in 82% yield (38 mg, 0.082 mmol). ³¹H NMR (400 MHz) δ: 4.94 (d, 2H, \( J = 3.6 \) Hz, H-1α); 4.66-4.51 (m, 10H, CH\text{H}_2\text{F}, CH\text{H}_2\text{F}); 4.26 (d, 3H, \( J = 8.0 \) Hz, H-1β); 4.15-4.01 (m, 5H, H-3α, CH\text{H}_2\text{F}); 3.94-3.68 (m, 13H, H-2α, H-4α, H-5α, CH\text{CH}_2\text{F}, CH\text{CH}_2\text{F}); 3.59-3.55 (m, 6H, H-2β, H-4β); 3.47 (q, 3H, \( J = 6.4 \) Hz, H-5β); 3.36 (dd, 3H, \( J = 2.4 \) Hz, 10.2 Hz, H-3β); 1.23 (d, 9H, \( J = 6.4 \) Hz, H-6β); 1.19 (d, 6H, \( J = 6.4 \) Hz, H-6α), 0.96-0.93 (m, 90H, (CH₃)₃CSi); 0.19-0.08 (m, 60H, CH₃Si). ¹³C-APT NMR (100 MHz) δ: 102.8 (C-1β); 98.3 (C-1α); 82.8 (d, \( J = 168 \) Hz, CH\text{CH}_2\text{F}); 82.6 (d, \( J = 168 \) Hz, CH\text{CH}_2\text{F}); 75.1 (C-4α); 74.4 (C-3β); 73.9 (C-4β); 71.3 (C-5β); 71.2 (C-3α); 68.3 (d, \( J = 20 \) Hz, CH\text{CH}_2\text{F}); 66.9 (d, \( J = 20 \) Hz, CH\text{CH}_2\text{F}); 63.8 (C-2β); 61.1 (C-2α); 26.3, 26.1, 26.1 ((CH₃)₃CSi); 18.6, 18.6, 18.5 (C₆Si); 17.5 (C-6β), 17.3 (C-6α); -3.5, -3.5, -3.6, -3.7, -4.3, -4.5, -4.5, -4.7 (CH₃Si). IR (thin film) ν: 2930, 2857, 2108, 1252, 1177, 1119, 1069, 1045, 1028. HRMS: [M+NH₄]⁺ calculated for C\text{2}₂\text{H}_\text{4}\text{eF}_\text{N}_\text{4}O₂Si₂: 481.30361; found 481.30338.
The title products (α/β 1:1) were isolated after column chromatography (hexane/EtO, 1:0 → 9:1) in 80% yield (35 mg, 0.080 mmol). 1H NMR (400 MHz) δ: 7.39-7.26 (m, 10H, CHα·α); 5.05-5.02 (m, 2H, 2x PhCH2); 4.94 (d, 1H, J = 3.5 Hz, H-1α); 4.67-5.51 (m, 6H, 2x PhCH2, CH3α, CH3β); 4.26 (d, 1H, J = 8.0 Hz, H-1β); 4.13 (dd, 1H, J = 2.8 Hz, 10.4 Hz, H-3α); 4.00-3.76 (m, 7H, H-2α, H-2β; H-5α; CH2CH2Fa, CH2CH2FB); 3.52-3.48 (m, 3H, H-3β, H-4α, H-5β); 3.38 (d, 1H, J = 2.8 Hz, H-4β); 1.21-1.18 (m, 6H, H-6α, H-6β); 0.98, 0.97 (s, 9H, (CH3)3Si); 0.24 (s, 3H, CH3Si); 0.20 (s, 6H, 2x CH3Si); 0.16 (s, 3H, CH3Si).

13C-APT NMR (100 MHz) δ: 138.5, 138.5 (Cα·α); 98.4 (C-1α); 82.7 (d, J = 168 Hz, CH3F); 82.6 (d, J = 168 Hz, CH3F); 80.7 (C-4α); 79.0 (C-4β); 75.6, 75.4 (PhCH2); 74.8 (C-5β); 71.4 (C-3β); 68.4 (d, J = 20 Hz, CH2CH2F); 67.1 (d, J = 20 Hz, CH2CH2F); 66.8 (C-5α); 64.6 (C-2β); 61.4 (C-2α); 25.9, 25.9 ((CH3)3Si); 18.1, 18.0 (C,Si); 16.7, 16.6 (C-6α, C-6β); -4.0, -4.3, -4.8, -5.1 (CH3Si).

IR (thin film) ν: 2930, 2886, 2857, 2108, 1254, 1169, 1119, 1065, 1045. HRMS: [M+NH4]⁺ calculated for C21H38FN4O4Si: 457.26429; found 457.26355.

The products (α/β 3:2) were obtained after column chromatography (toluene/EtOAc, 1:0 → 9:1 v/v), in 81% yield (35 mg, 0.081 mmol). 1H NMR (400 MHz) δ: 7.43-7.25 (m, 50H, CHα·α·α); 6.08-5.78 (m, 5H, CHFα·α, CHFβ·β); 4.95-4.91 (m, 7H, H-1α, PhCHHα, PhCHHβ); 4.74-4.59 (m, 14H, PhCH2); 4.24 (d, 2H, J = 8.0 Hz, H-1β); 4.01-3.73 (m, 24H, H-2α, H-2β, H-3α, H-4α, H-5α, CH2CHFα, CH2CHFβ·β); 3.54 (d, 2H, J = 2.4 Hz, H-4β); 3.43 (q, 2H, J = 6.4 Hz, H-5β); 3.31 (dd, 2H, J = 2.8 Hz, 10.0 Hz, H-3β); 1.20-1.17 (m, 15H, H-6α, H-6β). 13C-APT NMR (100 MHz) δ: 138.1, 138.0, 137.5, 137.5 (Cα·α·α); 128.6, 128.5, 128.3, 128.2, 128.0, 127.8, 127.8, 127.6 (CHα·α·α·α); 114.3 (CHFβ·β); 113.9 (CHF2α·α); 102.4 (C-1β); 99.0 (C-1α); 80.8 (C-3β); 77.6 (C-3α or C-5α); 75.9 (C-4α); 75.0 (PhCH2α); 74.7 (PhCH2β); 74.6 (C-4β); 72.8 (PhCH3β); 72.4 (PhCH2α); 70.9 (C-5β); 68.3 (t, J = 29 Hz, CH2CHF3β); 67.2 (C-3α or C-5α); 67.2 (t, J = 29 Hz, CH2CHF3β); 62.8 (C-2β); 59.4 (C-2α);...
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16.7, 16.6 (C-6α, C-6β). IR (thin film) ν: 2926, 2110, 1738, 1454, 1360, 1109, 1069. HRMS: [M+NH₄]⁺ calculated for C₂₂H₂₉F₂N₄O₄: 451.21514; found 451.21500.

2,2-difluoroethyl 2-azido-3,4-di-O-benzoyl-2-deoxy-α/β-L-fucopyranoside (C2)

The title compounds (α/β 3:2) were obtained after column chromatography (toluene/EtOAc, 1:0 → 9:1 v/v) in 74% yield (34 mg, 0.074 mmol). 8.07 (m, 5.4H, CH₉arom); 7.89-7.86 (m, 5.4H, CH₉arom); 7.64-7.60 (m, 2.7H, CH₉arom); 7.53-7.46 (m, 8.1H, CH₉arom); 7.35-7.31 (m, 5.4H, CH₉arom); 6.17-5.87 (m, 2.7H, CHF₂α, CHF₂β); 5.76-5.73 (m, 3.4H, H-3α, H-4α); 5.60 (d, 1H, J = 3.2 Hz, H-4β); 5.19-5.16 (m, 2.7H, H-1α, H-3β); 4.56 (d, 1H, J = 8.0 Hz, H-1β); 4.38 (q, 1H, J = 6.4 Hz, H-5α); 4.17-3.86 (m, 9.1H, H-2α, H-2β, H-5β, CH₂CH₂Fa, CH₂CH₂Fβ); 1.32-1.23 (m, 8.1H, H-6α, H-6β). ¹³C-APT NMR (100 MHz) δ: 165.7, 165.7, 165.4 (C₉Bz); 133.5, 133.5, 133.4, 133.3, 129.9, 129.8 (CH₉arom); 129.2, 129.1, 129.0 (C₉α, C₉arom); 129.0, 128.6, 128.4, 128.3 (CH₉arom); 114.0 (t, J = 240 Hz, CHF₂β); 113.7 (t, J = 240 Hz, CHF₂α); 102.6 (C-1β); 99.1 (C-1α); 71.9 (C-3β); 71.1 (C-3α or C-4α); 70.0, 69.9 (C-4β, C-5β); 69.0 (C-3α or C-4α); 68.8 (t, J = 30 Hz, CH₂CH₂Fβ); 67.4 (t, J = 30 Hz, CH₂CH₂Fa); 65.8 (C-5α); 61.2 (C-2β); 57.9 (C-2α); 16.2 (C-6β), 16.0 (C-6α). IR (thin film) ν: 2926, 2110, 1726, 1450, 1261, 1163, 1107, 1094, 1067. HRMS: [M+Na]⁺ calculated for C₂₂H₂₁F₂N₃O₆Na: 484.12906; found 484.12894.

2,2-difluoroethyl 2-azido-4-O-benzyl-3-O-benzyl-2-deoxy-α/β-L-fucopyranoside (C3)

The products (α/β 3:1) were obtained after column chromatography (toluene/EtOAc, 1:0 → 19:1) in 76% yield. (34 mg, 0.076 mmol), accompanied by a small amount of inseparable, hydrolyzed donor. ¹H NMR (400 MHz) δ: 8.12-8.07 (m, 8H, CH₉arom); 7.60-7.58 (m, 4H, CH₉arom); 7.49-7.44 (m, 10H, CH₉arom); 7.35-7.25 (m, 18H, CH₉arom); 6.12-5.82 (m, 4H, CHF₂α, CHF₂β); 5.70 (d, 3H, J = 2.8 Hz, H-4α); 5.45 (d, 1H, J = 2.8 Hz, H-4β); 5.01 (d, 3H, J = 3.6 Hz, H-1α); 4.83 (d, 3H, J = 10.8 Hz, PhCHHα); 4.79 (d, 1H, J = 11.6 Hz, PhCHHβ); 4.56-4.53 (d, 4H, PhCHHα, PhCHHβ); 4.33 (d, 1H, J = 8.0 Hz, H-1β); 4.19 (q, 3H, J = 6.4 Hz, H-5α); 4.08 (dd, 3H, J = 3.2 Hz, 10.8 Hz, H-3α); 4.03-3.69 (m, 13H, H-2α, H-2β, H-5β, CH₂CH₂Fa, CH₂CH₂Fβ); 3.47 (dd, 1H, J = 3.6 Hz, 10.8 Hz, H-3β); 1.31-
The title compounds (α/β 1:1) were obtained after column chromatography (toluene/EtOAc, 1:0 → 9:1) in 80% yield (36 mg, 0.080 mmol). ¹H NMR (400 MHz) δ: 8.10-8.06 (m, 4H, CH₆arom); 7.63-7.59 (m, 2H, CH₂arom); 7.49-7.46 (m, 4H, CH₂arom); 7.26-7.20 (m, 10H, CH₂arom); 6.11-5.82 (m, 2H, CHF₂α, CHF₂β); 5.54 (dd, 1H, J = 3.2 Hz, 11.2 Hz, H-3α); 5.04 (d, 1H, J = 3.6 Hz, H-1α); 4.95 (dd, 1H, J = 2.8 Hz, 10.8 Hz, H-3β); 4.72-4.69 (d, 2H, J = 11.6 Hz, 2x PhCHH); 4.57-4.52 (m, 2H, 2x PhCHH); 4.42 (d, 1H, J = 8.8 Hz, H-1β); 4.14-4.378 (m, 9H, H-2α, H-2β, H-4α, H-4β, H-5α, CH₂CHF₂α, CH₂CHF₂β); 3.68 (q, 1H, J = 6.4 Hz, H-5β); 1.30-1.20 (m, 6H, H-6α, H-6β). ¹³C-APT NMR (100 MHz) δ: 165.8 (CD₂); 137.4, 137.3 (C₆arom); 133.6, 133.6, 130.2, 129.9 (CH₂arom); 129.3 (C₆arom); 129.0, 128.6, 128.5, 128.4, 128.3, 128.2, 128.0, 127.9 (CH₂arom); 114.1 (t, J = 240 Hz, CHF₂); 113.8 (t, J = 240 Hz, CHF₂); 102.4 (C-1β); 99.0 (C-1α); 77.0, 75.7 (C-2α, C-2β); 75.6, 75.5 (PhCH₂); 74.7 (C-3β); 71.9 (C-3α); 70.9 (C-5β); 68.7-67.3 (m, 2C, CH₂CHF₂α, CH₂CHF₂β); 66.9 (C-5α); 61.1 (C-2β); 57.9 (C-2α); 16.5, 16.3 (C-6α, C-6β). IR (thin film) ν: 2924, 2110, 1721, 1452, 1265, 1169, 1096, 1069, 1026. HRMS: [M+NH₄]⁺ calculated for C₂₂H₂₇F₂N₂O₅: 465.19440; found 465.19434.

The title products (α/β 5:2) were obtained after column chromatography (hexane/Et₂O, 1:0 → 19:1 v/v) in 75% yield (36 mg, 0.075 mmol). ¹H NMR (400 MHz) δ: 6.09-5.79 (m, 7H, CHF₂α,

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**2,2-difluoroethyl 2-azido-3-O-benzoyl-4-O-benzyl-2-deoxy-α/β-l-fucopyranoside (C4)**

![Chemical structure of C4]

**2,2-difluoroethyl 2-azido-2-deoxy-3,4-di-O-(tert-butyldimethylsilyl)-α/β-l-fucopyranoside (C5)**

![Chemical structure of C5]
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CHF$_2$β) 4.93 (d, 5H, $J = 3.2$ Hz, H-1α); 4.26 (d, 2H, $J = 8.0$ Hz, H-1β); 4.01-3.73 (m, 27H, H-2α, H-3α, H-5α, OCH$_3$CHF$_2$α, OCH$_2$CHF$_2$β); 3.71 (d, 5H, $J = 2.0$ Hz, H-4α); 3.58-3.53 (m, 4H, H-2β, H-4β); 3.47 (q, 2H, $J = 6.4$ Hz, H-5β); 3.36 (dd, 2H, $J = 2.4$ Hz, 10.4 Hz, H-3β); 1.23 (d, 6H, $J = 6.4$ Hz, H-6β); 1.19 (d, 15H, $J = 6.4$ Hz, H-6α); 0.96-0.89 (m, 126H, ((C$_3$H$_7$)$_3$Si); 0.18-0.09 (m, 84H, CH$_2$Si).

$^{13}$C-APT NMR (100 MHz) δ: 114.4 (t, $J = 240$ Hz, CHF$_2$β); 114.1 (t, $J = 240$ Hz, CHF$_2$α); 102.8 (C-1β); 98.9 (C-1α); 75.0 (C-4α); 74.3 (C-3β); 73.8 (C-4β); 71.5 (C-3α); 68.5 (C-5α); 68.2 (t, $J = 29$ Hz, CH$_2$CHF$_2$β); 67.1 (t, $J = 29$ Hz, CH$_2$CHF$_2$α); 63.8 (C-2β); 61.0 (C-2α); 26.3, 26.1 ((CH$_3$)$_3$Si); 18.6, 18.5 (C$_6$Si); 17.4 (C-6β); 17.3 (C-6α); -3.5, -3.5, -3.8, -4.4, -4.5, -4.7 (CH$_2$Si). IR (thin film) ν: 2930, 2859, 2108, 1252, 1177, 1113, 1069, 1043, 1028. HRMS: [M-N$_2$+H]$^+$ calculated for C$_{29}$H$_{42}$F$_2$N$_2$O$_4$Si$_2$: 454.2536; found 454.2629.

2,2-difluoroethyl 2-azido-4-O-benzyl-2-deoxy-3-O-(tert-butyldimethylsilyl)-α/β-l-fucopyranoside (C6)

The title products (α/β 2:1) were obtained after chromatography (hexane/Et$_2$O, 1:0 → 9:1 v/v) in 87% yield (40 mg, 0.087 mmol). $^1$H NMR (400 MHz) δ: 7.39-7.25 (m, 7.5H, CH$_3$-arom); 6.08-5.81 (m, 1.5H, CHF$_2$α, CHF$_2$β); 5.05-5.02 (d, 1.5H, $J = 11.2$ Hz, PhCHHα, PhCHHβ); 4.93 (d, 1H, $J = 3.6$ Hz, H-1α); 4.62-4.56 (m, 1.5H, PhCHHα, PhCHHβ); 4.25 (d, 0.5H, $J = 8.0$ Hz, H-1β); 4.08 (dd, 1H, $J = 2.8$ Hz, 10.4 Hz, H-3α); 3.94 (q, 1H, $J = 6.4$ Hz, H-5α); 3.82-3.73 (m, 4H, H-2α, CH$_2$CHF$_2$α, CH$_2$CHF$_2$β); 3.66 (dd, 0.5H, $J = 8.0$ Hz, 10.4 Hz, H-2β); 3.52-3.50 (m, 2H, H-3β, H-4α, H-5β); 3.39 (d, 0.5H, $J = 2.4$ Hz, H-4β); 1.26-1.18 (m, 4.5H, H-6α, H-6β); 0.98 (s, 9H, (CH$_3$)$_3$Si); 0.97 (s, 4.5H, (CH$_3$)$_3$Si); 0.24 (s, 3H, CH$_3$Si); 0.20 (s, 4.5H, CH$_3$Siα, CH$_3$Siβ); 0.16 (s, 1.5H, CH$_3$Si). $^{13}$C-APT NMR (100 MHz) δ: 138.4, 138.4 (C$_{q-arom}$); 128.3, 128.2, 128.1, 127.9, 127.7, 127.7 (CH$_{arom}$); 114.3 (t, $J = 240$ Hz, CHF$_2$β); 114.0 (t, $J = 240$ Hz, CHF$_2$α); 102.6 (C-1β); 99.0 (C-1α); 80.5 (C-4α); 78.9 (C-4β); 75.7, 75.5 (PhCH$_2$); 74.7 (C-3β or C-5β); 71.3 (C-3α); 70.7 (C-3β or C-5β); 68.4 (t, $J = 27$ Hz, CH$_2$CHF$_2$β); 67.3 (t, $J = 29$ Hz, CH$_2$CHF$_2$α); 67.3 (C-5α); 64.5 (C-2β); 61.3 (C-2α); 25.9, 25.8 ((CH$_3$)$_3$Si); 18.1, 18.0 (C$_6$Si); 16.7, 16.6 (C-6, C-6'); -4.1, -4.3, -4.8, -5.1 (CH$_3$Si). IR (thin film) ν: 2930, 2110, 1260, 1169, 1115, 1070, 1047. HRMS: [M+NH$_4$]$^+$ calculated for C$_{32}$H$_{37}$F$_2$N$_2$O$_4$Si: 475.25463; found 475.25467.
The title compound was obtained after column chromatography (hexane/EtOAc 1:0 → 9:1 v/v), in 80% yield (36 mg, 0.080 mmol, 80%). ¹H NMR (400 MHz) δ: 7.44-7.25 (m, 10H, CH_arom); 4.96-4.92 (m, 2H, PhCH_H, H-1); 4.75 (s, 2H, PhCH_2); 4.60 (d, 1H, J = 11.6 Hz, PhCH_H); 3.99-3.88 (m, 5H, H-2, H-3, H-5, CH_2CF_3); 3.54 (d, 1H, J = 2.4 Hz, H-4); 1.18 (d, 3H, J = 6.4 Hz, H-6). ¹³C-APT NMR (100 MHz) δ: 138.0, 137.5 (C_q_arom); 128.6, 128.3, 128.3, 128.0, 127.8, 127.8 (CH_arom); 123.6 (q, J = 277 Hz, CF_3); 99.0 (C-1); 77.4 (C-3 or C-5); 75.9 (C-4); 75.0, 72.5 (PhCH_2); 67.5 (C-3 or C-5); 64.9 (q, J = 35 Hz, CH_2CF_3); 59.2 (C-2); 16.7 (C-6). ¹³C-GATED NMR (100 MHz) δ: 99.0 (d, J = 170 Hz, C-1). IR (thin film) ν: 2927, 2108, 1454, 1356, 1279, 1163, 1082, 1051. HRMS: [M+Na]^+ calculated for C_{22}H_{24}F_3N_3O_4Na: 474.16111; found 474.16088.

The title compounds (α/β 10:1) were isolated after column chromatography (hexane/EtOAc. 1:0 → 4:1) in 50% yield (24 mg, 0.050 mmol). NMR data is reported for the α-product only. ¹H NMR (400 MHz) δ: 8.04-8.02 (m, 2H, CH_arom); 7.89-7.86 (m, 2H, CH_arom); 7.66-7.61 (m, 1H, CH_arom); 7.54-7.45 (m, 3H, CH_arom); 7.36-7.32 (m, 2H, CH_arom); 5.77-7.73 (m, 2H, H-3, H-4); 5.20 (d, 1H, J = 3.6 Hz, H-1); 4.37 (q, 1H, J = 6.4 Hz, H-5); 4.08 (q, 2H, J = 8.4 Hz, CH_2CF_3); 3.95 (dd, 1H, J = 3.2 Hz, 11.4 Hz, H-2); 1.26 (d, 3H, J = 6.8 Hz, H-6). ¹³C-APT NMR (100 MHz) δ: 165.6, 165.3 (CO_2); 133.5, 133.4, 129.9, 129.8 (CH_arom); 129.2, 129.0 (C_q_arom); 128.6, 128.3 (CH_arom); 123.4 (q, J = 276 Hz, CF_3); 99.2 (C-1); 71.0 (C-3); 68.8 (C-4); 65.8 (C-5); 65.3 (q, J = 35 Hz, CH_2CF_3); 57.7 (C-2); 16.0 (C-6). IR (thin film) ν: 2928, 2110, 1724, 1452, 1279, 1163, 1157, 1109, 1094, 1069, 1026. HRMS: [M+Na]^+ calculated for C_{22}H_{20}F_3N_3O_6Na: 502.11964; found 502.11947.
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2,2,2-trifluoroethyl 2-azido-4-O-benzoyl-3-O-benzyl-2-deoxy-α-L-fucopyranoside (D3)

The title compound was obtained after column chromatography (hexane/EtO 1:0 → 9:1 v/v) in 45% yield (21 mg, 0.045 mmol). NMR data is reported for the α-isomer only. ¹H NMR (400 MHz) δ: 8.08 (d, 2H, J = 7.2 Hz, CH₉arom); 7.59 (t, 1H, J = 7.6 Hz, CH₉arom); 7.46 (t, 2H, J = 8.0 Hz, CH₉arom); 7.34-7.24 (m, 5H, CH₉arom); 5.72 (d, 1H, J = 2.8 Hz, H-4); 5.05 (d, 1H, J = 3.6 Hz, H-1); 4.85 (d, 1H, J = 10.4 Hz, PhCHH); 4.55 (d, 1H, J = 10.8 Hz, PhCHH); 4.19 (q, 1H, J = 6.4 Hz, H-5); 4.11 (dd, 1H, J = 2.8 Hz, 10.4 Hz, H-3); 4.01 (q, 2H, J = 8.4 Hz, CH₂CF₃); 3.80 (dd, 1H, J = 3.6 Hz, 10.4 Hz, H-2); 1.24 (d, 3H, J = 6.8 Hz, H-6). ¹³C-APT NMR (100 MHz) δ: 166.0 (CO_Bz); 137.0 (C_qarom); 133.4, 129.8 (CH_arom); 129.5 (C_qarom); 128.5, 128.4, 128.3, 127.9 (CH_arom); 123.5 (q, J = 277 Hz, CF₃); 99.1 (C-1); 74.1 (C-3); 71.6 (PhCH₂); 69.6 (C-4); 66.2 (C-5); 65.3 (q, J = 35 Hz, CH₂CF₃); 58.9 (C-2); 16.3 (C-6). IR (thin film) ν: 2924, 2110, 1721, 1452, 1267, 1157, 1111, 1084, 1055, 1026. HRMS: [M+H]^+ calculated for C₂₂H₂₃F₃N₃O₅: 466.15843; found 466.15813.

2,2,2-trifluoroethyl 2-azido-3-O-benzoyl-4-O-benzyl-2-deoxy-α/β-L-fucopyranoside (D4)

The title compounds (α/β 7:1) were obtained after column chromatography (hexane/EtO 1:0 → 4:1 v/v), in 77% yield (36 mg, 0.077 mmol). ¹H NMR (400 MHz) δ: 8.10-8.06 (m, 2.3H, CH_arom); 7.63-7.59 (m, 1.2H, CH_arom); 7.49-7.46 (m, 2.5H, CH_arom); 7.29-7.21 (m, 6H, CH_arom); 5.54 (dd, 1H, J = 2.8 Hz, 11.2 Hz, H-3α); 5.07 (d, 1H, J = 3.6 Hz, H-1α); 4.95 (dd, 0.15H, J = 2.8 Hz, 11.2 Hz, H-3β); 4.72-4.69 (m, 1.15H, PhCΗHα, PhCΗHβ); 4.57-4.52 (m, 1.15H, PhCΗHα, PhCΗHβ); 4.48 (d, 0.15H, J = 8.0 Hz, H-1β); 4.11 (q, 1H, J = 6.8 Hz, H-5α); 4.07-3.95 (m, 4.45H, H-2α, H-4α, CH₂CF₃α, H-2β, CH₂CF₃β); 3.82 (d, 0.15H, J = 2.8 Hz, H-4β); 3.68 (q, 0.15H, J = 6.8 Hz, H-5β); 1.26-1.22 (m, 3.45H, H-6α, H-6β). ¹³C-APT NMR (100 MHz) δ: 165.8 (CO Bz); 137.3 (C_qarom); 133.6, 129.9 (CH_arom); 129.1 (C_qarom); 128.6, 128.4, 128.3, 128.2, 128.0 (CH_arom); 123.5 (q, J = 277 Hz, CF₃α); 102.0 (C-1β); 99.1 (C-1α); 76.9 (C-4α); 75.6 (PhCH₂α); 75.6 (C-4β); 75.5 (PhCH₂β); 74.6 (C-3β); 71.8 (C-3α); 71.0 (C-5β); 67.2 (C-5α); 65.0 (q, J = 35 Hz, CH₂CF₃α); 61.1 (C-2β); 57.6 (C-2α); 16.4 (C-6β); 16.3 (C-6α). IR (thin film) ν: 2924, 2110, 1721, 1452, 1267, 1155, 1105, 1096, 1070, 1045, 1026. HRMS: [M+NH₄]^+ calculated for C₂₂H₂₆F₃N₄O₅: 483.18498; found 483.18487.
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors

2,2,2-trifluoroethyl 2-azido-2-deoxy-3,4-di-O-(tert-butylidemethylsilyl)-α-L-fucopyranoside (D5)

The title compound were isolated after column chromatography (hexane/Et₂O, 1:0 → 49:1) in 84% yield (42 mg, 0.084 mmol). NMR data is reported for the α-isomer only. 1H NMR (400 MHz) δ: 4.97 (d, 1H, J = 3.2 Hz, H-1); 4.01 (dd, 1H, J = 2.0 Hz, 10.4 Hz, H-3); 3.98-3.88 (m, 3H, H-5, CH₂CF₃); 3.79 (dd, 1H, J = 3.6 Hz, 10.4 Hz, H-2); 3.72 (d, 1H, J = 1.2 Hz, H-4); 1.20 (d, 3H, J = 6.4 Hz, H-6); 0.96, 0.94 (s, 9H, (CH₃)₃Si); 0.19 (s, 3H, CH₂Si); 0.16-0.15 (m, 6H, CH₂Si); 0.07 (s, 3H, CH₂Si). 13C-APT NMR (100 MHz) δ: 123.7 (q, J = 276 Hz, CF₃); 98.8 (C-1); 74.9 (C-4); 70.9 (C-3); 68.8 (C-5); 64.7 (q, J = 35 Hz, CH₂CF₃); 60.8 (C-2); 26.2, 26.1 ((CH₃)₃Si); 18.6, 18.5 (C₅Si); 17.2 (C-6); -3.5, -3.8, -4.5, -4.8 (CH₂Si). IR: 2932, 2859, 2108, 1279, 1275, 1177, 1045. HRMS: [M+H-N₂]⁺ calculated for C₂₀H₄₁F₃NO₄Si₂: 472.25207; found 472.25180.

2,2,2-trifluoroethyl 2-azido-4-O-benzyl-2-deoxy-3-O-(tert-butylidemethylsilyl)-α-L-fucopyranoside (D6)

The title product was obtained after column chromatography (hexane/Et₂O, 1:0 → 9:1 v/v) in 90% yield (43 mg, 0.090 mmol). 1H NMR (400 MHz) δ: 7.39-7.25 (m, 5H, CH₅arom); 5.04 (d, 1H, J = 11.2 Hz, PhCH₂); 4.96 (d, 1H, J = 3.6 Hz, H-1); 4.57 (d, 1H, J = 11.2 Hz, PhCH₂H); 4.10 (dd, 1H, J = 2.4 Hz, 10.2 Hz, H-3); 3.97-3.91 (m, 3H, H-5, CH₂CF₃); 3.81 (dd, 1H, J = 3.6 Hz, 10.0 Hz, H-2); 3.53 (d, 1H, J = 2.0 Hz, H-4); 1.20 (d, 3H, J = 6.4 Hz, H-6); 0.98 (d, 9H, (CH₃)₃Si); 0.24, 0.20 (s, 3H, CH₂Si). 13C-APT NMR (100 MHz) δ: 138.4 (Cqarom); 128.3, 128.1, 127.9 (CH₅arom); 123.6 (q, J = 277 Hz, CF₃); 99.0 (C-1); 8.4 (C-4); 75.7 (PhCH₂); 71.1 (C-3); 67.7 (C-5); 64.9 (q, J = 35 Hz, CH₂CF₃); 61.1 (C-2), 25.9 ((CH₃)₃Si); 18.1 (C₅Si); 16.5 (C-6); -4.1, -5.1 (CH₂Si). IR (thin film) ν: 2930, 2859, 2108, 1279, 1261, 1163, 1121, 1084, 1045. HRMS: [M+NH₄]⁺ calculated for C₂₂H₃₆F₃N₄O₄Si: 493.24524; found 493.24515.
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Cyclohexyl 2-azido-3,4-di-O-benzyl-2-deoxy-α/β-L-fucopyranoside (E1)

The title compounds (α/β 1:2) were obtained after column chromatography (hexane/EtOAc 1:0 → 9:1 v/v), in 75% yield (34 mg, 0.075 mmol). 1H NMR (400 MHz) δ: 7.44-7.25 (m, 30H, CH\textsubscript{arom}); 5.02 (d, 1H, J = 3.6 Hz, H-1α; 4.94-4.91 (m, 3H, PhCH\textsubscript{Ar}Hα, PhCH\textsubscript{Ar}Hβ); 4.77-4.60 (m, 12H, PhCH\textsubscript{2}α, PhCH\textsubscript{2}β); 4.28 (d, 2H, J = 8.0 Hz, H-1β); 4.02-3.96 (m, 2H, H-3α, H-5α); 3.81-3.74 (m, 4H, H-2α, H-2β, H-4α); 3.65 (tt, 2H, J = 7.6 Hz, 9.6 Hz, CH\textsubscript{CH}); 3.58 (tt, 1H, J = 7.6 Hz, 9.6 Hz, CH\textsubscript{CH}); 3.51 (d, 2H, J = 2.4 Hz, H-4β); 3.38 (q, 2H, J = 6.4 Hz, H-5β); 3.26 (dd, 2H, J = 2.8 Hz, 10.4 Hz, H-3β), 1.90-1.62 (m, 12H, CH\textsubscript{2}CH); 1.50-1.34 (m, 10H, CH\textsubscript{2}CH); 1.25-1.15 (m, 15H, H-6α, H-6β, CH\textsubscript{2}CH). 13C-APT NMR (100 MHz) δ: 138.2, 137.8 (C\textsubscript{arom}); 128.5, 128.3, 128.2, 128.1, 127.9, 127.8, 127.7, 127.4, 127.6 (CH\textsubscript{arom}); 100.3 (C-1β); 96.6 (C-1α); 80.9 (C-3β); 77.6 (CH\textsubscript{CHβ}); 76.2 (C-4α); 76.1 (CH\textsubscript{CHα}); 74.8 (C-4β); 74.5, 72.6, 72.2 (PhCH\textsubscript{2}); 70.4 (C-5β); 66.5 (C-5α); 63.2 (C-2β); 59.4 (C-2α); 33.3, 31.5, 31.4, 25.6, 25.5, 24.1, 23.9, 23.8 (CH\textsubscript{2}CH); 17.0 (C-6β); 16.7 (C-6α). IR (thin film) ν: 2932, 2855, 2106, 1454, 1359, 1107, 1067, 1038. HRMS: [M+NH\textsubscript{4}]\textsuperscript{+} calculated for C\textsubscript{29}H\textsubscript{37}N\textsubscript{4}O\textsubscript{4}: 469.28093; found 469.28096.

Cyclohexyl 2-azido-3,4-di-O-benzoyl-2-deoxy-α/β-L-fucopyranoside (E2)

The title compounds (α/β 1:9) were obtained after column chromatography (hexane/EtOAc 1:0 → 9:1 v/v), in 38% yield (18 mg, 0.038 mmol). NMR data is reported only for the β-glycoside. 1H NMR (400 MHz) δ: 8.09-8.07 (m, 2H, CH\textsubscript{arom}); 7.89-7.85 (m, 2H, CH\textsubscript{arom}); 7.64-7.60 (m, 1H, CH\textsubscript{arom}); 7.52-7.45 (m, 3H, CH\textsubscript{arom}); 7.32 (t, 2H, J = 7.6 Hz, CH\textsubscript{arom}); 5.56 (d, 1H, J = 3.6 Hz, H-4); 5.15 (dd, 1H, J = 3.6 Hz, 10.8 Hz, H-3); 4.61 (d, 1H, J = 8.0 Hz, H-1); 3.95-3.88 (m, 2H, H-2, H-5); 3.79 (tt, 1H, J = 7.6 Hz, 9.6 Hz, CH\textsubscript{CH}); 2.03-2.01 (m, 2H, CH\textsubscript{2}CH); 1.81-1.79 (m, 2H, CH\textsubscript{2}CH); 1.57-1.43 (m, 3H, CH\textsubscript{2}CH); 1.37-1.22 (m, 8H, H-6, H-6); 1.37-1.22 (m, 8H, H-6, H-6); 1.33, 129.9, 129.7 (CH\textsubscript{arom}); 129.3, 129.1 (C\textsubscript{arom}); 128.5, 128.3 (CH\textsubscript{arom}); 100.5 (C-1); 78.3 (CH\textsubscript{CH}); 71.9 (C-3); 70.3 (C-4); 69.4 (C-5); 61.5 (C-2); 33.5, 31.6, 25.5, 24.1, 23.9 (CH\textsubscript{2}CH); 16.4 (C-6). IR (thin film) ν: 2934, 2857, 1710, 1724, 1450, 1281, 1263, 1173, 1107, 1096, 1069, 1026. HRMS: [M+Na]\textsuperscript{+} calculated for C\textsubscript{26}H\textsubscript{28}N\textsubscript{4}NaO\textsubscript{6}: 502.19486; found 502.19479.
The title compounds (α/β 1:4) were obtained after column chromatography (hexane/EtO 1:0 → 9:1 v/v), in 71% yield (33 mg, 0.071 mmol). 1H NMR (400 MHz) δ: 8.14-8.07 (m, 2.5H, CHarom); 7.60-7.56 (m, 1.25H, CHarom); 7.48-7.44 (m, 2.5H, CHarom); 7.35-7.24 (m, 6.25H, CHarom); 5.70 (d, 0.25H, / = 2.4 Hz, H-4α); 5.52 (dd, 1H, / = 0.8 Hz, 3.2 Hz, H-4β); 5.11 (d, 0.25H, / = 3.6 Hz, H-1α); 4.84 (d, 0.25H, / = 10.4 Hz, PhCH(Hα)); 4.78 (d, 1H, / = 11.6 Hz, PhCH(Hβ)); 4.56-4.52 (m, 1.25H, PhCHHβ); 4.39 (d, 1H, / = 8.4 Hz, H-1β); 4.26 (q, 0.25H, / = 7.2 Hz, H-5α); 4.13 (dd, 0.25H, / = 3.6 Hz, 10.6 Hz, H-3α); 3.74-3.60 (m, 3.5H, H-2α, H-2β, H-5β, CHβ); 3.41 (dd, 1H, / = 3.2 Hz, 10.2 Hz, H-3β); 1.98-1.77 (m, 5H, CH₂Cγ); 1.55-1.43 (m, 4H, CH₂Cγ); 1.31-1.20 (m, 7.25H, H-6α, H-6β, CH₂Cγ). ¹³C-APT (100 MHz) δ: 166.30 (COBz); 137.2 (Cqarom); 133.3, 133.2, 130.1, 129.8 (CHarom); 129.5 (Cqarom); 128.4, 128.4, 128.2, 128.1, 127.8, 127.8 (CHarom); 100.3 (C-1β); 96.7 (C-1α); 78.0 (CHβ); 77.5 (C-3β); 74.1 (C-3α); 71.5 (PhCH₂β); 71.5 (PhCH₂α); 70.1 (C-4α); 69.4 (C-5β); 69.0 (C-4β); 65.2 (C-5α); 62.9 (C-2β); 59.2 (C-2α); 33.5, 33.3, 31.6, 31.5, 25.5, 24.1, 23.9, 23.8 (CH₂Cγ); 16.6 (C-6β); 16.3 (C-6α). IR (thin film) ν: 2922, 2110, 1720, 1446, 1265, 1107, 1068. HRMS: [M+H]+ calculated for C₂₅H₂₃N₂O₅: 466.23365; found 466.23352.

**Cyclohexyl 2-azido-3-O-benzoyl-4-O-benzyl-2-deoxy-α/β-L-fucopyranoside (E4)**

The title compounds (α/β 1:4) were obtained after column chromatography (hexane/EtO 1:0 → 9:1 v/v), in 71% yield (35 mg, 0.075 mmol). 1H NMR (400 MHz) δ: 8.10-8.06 (m, 10H, CHarom); 7.62-7.58 (m, 5H, CHarom); 7.48-7.45 (m, 11H, CHarom); 7.25-7.18 (m, 28H, CHarom); 5.59 (dd, 1H, / = 2.4 Hz, 11.2 Hz, H-3α); 5.13 (d, 1H, / = 3.2 Hz, H-1α); 4.93 (dd, 4H, / = 2.8 Hz, 10.8 Hz, H-3β); 4.71-4.69 (m, 5H, PhCHH); 4.57-4.52 (m, 5H, PhCHH); 4.47 (d, 4H, / = 8.0 Hz, H-1β); 4.19 (q, 1H, / = 6.4 Hz, H-5α); 3.98-3.93 (m, 5H, H-2β, H-4α); 3.88 (dd, 1H, / = 3.4 Hz, 11.2 Hz, H-2α); 3.76-3.70 (m, 8H, H-4β, CH₂β); 3.66-3.61 (m, 5H, H-5β, CH₂α); 1.93-1.75 (m, 22H, CH₂Cγ); 1.52-1.43 (m, 18H, CH₂Cγ); 1.32-1.18 (m, 38H, H-6α, H-6β, CH₂Cγ). ¹³C-APT NMR (100 MHz) δ: 165.8 (CO Bz); 137.6, 137.5 (Cqarom); 133.5, 129.9 (CHarom); 129.2 (Cqarom); 128.5, 128.3, 128.2, 128.2, 127.8, 127.8 (CHarom); 100.3 (H-1β); 96.7 (H-1α); 77.6 (CH₃β); 77.4 (H-4α); 76.5 (CH₃α); 75.9 (C-4β); 75.5
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(Ph<sub>2</sub>CH<sub>α</sub>); 75.3 (Ph<sub>2</sub>CH<sub>β</sub>); 74.8 (C-3β); 72.0 (C-3α); 70.4 (C-5β); 66.2 (C-5α); 61.4 (C-2β); 57.8 (C-2α); 33.4, 33.3, 31.4, 29.7, 25.5, 23.9, 23.8 (CH<sub>2</sub>C<sub>6</sub>H<sub>5</sub>); 16.7 (C-6β); 16.4 (C-6α). IR (thin film) ν: 2932, 2857, 2108, 1452, 1265, 1173, 1096, 1069, 1038, 1026. HRMS: [M+NH<sub>4</sub>]<sup>+</sup> calculated for C<sub>26</sub>H<sub>33</sub>N<sub>4</sub>O<sub>5</sub>: 483.26020; found 483.26018.

**Cyclohexyl 2-azido-2-deoxy-3,4-di-O-(tert-butyldimethylsilyl)-α/β-l-fucopyranoside (E5)**

\[
\begin{array}{c}
\text{TBSO} \\
\text{O}
\end{array}
\]

The products (α/β 1:3) were obtained after column chromatography (hexane/Et<sub>2</sub>O, 1:0 → 9:1) in 80% yield (40 mg, 0.080 mmol). <sup>1</sup>H NMR (400 MHz) δ: 5.04 (d, 1H, /J = 3.6 Hz, H-1α); 4.28 (d, 3H, /J = 7.6 Hz, H-1β); 4.05 (dd, 1H, /J = 2.4 Hz, 10.4 Hz, H-3α); 3.94 (q, 1H, /J = 6.8 Hz, H-5α); 3.69-3.56 (m, 6H, H-2α, H-4α, OCH<sub>3</sub>α, OCH<sub>3</sub>β); 3.55 (d, 3H, /J = 2.4 Hz, H-4β); 3.51 (dd, 3H, /J = 8.0 Hz, 10.2 Hz, H-2β); 3.42 (q, 3H, /J = 6.4 Hz, H-5β); 3.33 (dd, 3H, /J = 2.4 Hz, 10.4 Hz, H-3β); 1.97-1.25 (m, 40H, CH<sub>2</sub>C<sub>6</sub>H<sub>5</sub>); 1.22 (d, 9H, /J = 6.4 Hz, H-6β); 1.17 (d, 3H, /J = 6.4 Hz, H-6α); 0.96-0.90 (m, 72H, (CH<sub>3</sub>)<sub>3</sub>Si); 0.18-0.08 (m, 48H, CH<sub>2</sub>Si). <sup>13</sup>C-APT NMR (100 MHz) δ: 100.6 (C-1β); 96.3 (C-1α); 77.4 (CH<sub>2</sub>β); 75.6 (CH<sub>2</sub>α); 74.5 (C-3β); 74.0 (C-4β); 71.2 (C-3α); 71.0 (C-5β); 67.8 (C-5α); 64.2 (C-2β); 60.9 (C-2α); 33.5, 33.3, 31.8, 31.4 (CH<sub>2</sub>C<sub>6</sub>H<sub>5</sub>); 26.2, 26.1 ((CH<sub>3</sub>)<sub>3</sub>Si); 25.7, 25.6, 24.1, 24.0, 23.9, 23.7 (CH<sub>2</sub>C<sub>6</sub>H<sub>5</sub>); 18.6, 18.5 (C<sub>3</sub>Si); 17.7 (C-6β); 17.3 (C-6α); -3.4, -3.6, -4.3, -4.4, -4.5, -4.7 (CH<sub>3</sub>Si). IR (thin film) ν: 2930, 2857, 2110, 1252, 1173, 1096, 1069, 1026. HRMS: [M+Na]<sup>+</sup> calculated for C<sub>24</sub>H<sub>49</sub>N<sub>4</sub>O<sub>4</sub>Si<sub>2</sub>Na: 522.31538; found 522.31506.

**Cyclohexyl 2-azido-4-O-benzyl-3-O-(tert-butyldimethylsilyl)-2-deoxy-α/β-l-fucopyranoside (E6)**

\[
\begin{array}{c}
\text{TBSO} \\
\text{O}
\end{array}
\]

The title compounds (α/β 1:2) were obtained after column chromatography (hexane/Et<sub>2</sub>O, 1:0 → 19:1), in 80% yield (38 mg, 0.080 mmol). <sup>1</sup>H NMR (400 MHz) δ: 7.39-7.26 (m, 15H, CH<sub>arom</sub>); 5.03-5.01 (m, 4H, H-1α, PhCH=CHα, PhCH=CHβ); 4.61-4.55 (m, 3H, PhCH=CHα, PhCH=CHβ); 4.28 (d, 2H, /J = 8.0 Hz, H-1β); 4.14 (broad doublet, /J = 8.4 Hz, H-3α); 4.00 (q, 1H, /J = 6.4 Hz, H-5α); 3.67-3.43 (m, 11H, H-2α, H-2β, H-3β, H-4α, H-5β, OCH<sub>3</sub>α, OCH<sub>3</sub>β); 3.36 (bs, 2H, H-4β); 1.89-1.11 (m, 39H, CH<sub>2</sub>C<sub>6</sub>H<sub>5</sub>/β, 74
Methyl 2-O-(2-azido-3,4-di-O-benzyl-2-deoxy-α/β-L-fucopyranosyl)-3-O-benzyl-4,6-O-benzylidene-α-D-mannopyranoside (F1)

The product was obtained after size-exclusion chromatography (CH₂Cl₂/MeOH, 1:1 v/v), in 68% yield (49 mg, 0.068 mmol). NMR data is reported for the α-linked fucoside only. ¹H NMR (400 MHz) δ: 7.53-7.50 (m, 2H, CH₆arom); 7.44-7.23 (m, 18H, CH₆arom); 5.64 (s, 1H, PhCH₂); 4.95 (d, 1H, J = 3.6 Hz, H-1'); 4.90 (d, 1H, J = 11.2 Hz, PhCHH); 4.79-4.69 (m, 5H, H-1, PhCH₂); 4.59 (d, 1H, J = 11.6 Hz, PhCHH); 4.37 (q, 1H, J = 6.4 Hz, H-5'); 4.25 (dd, 1H, J = 4.8 Hz, 10.2 Hz, H-6); 4.19-4.13 (m, 3H, H-2, H-4, H-3'); 3.98 (dd, 1H, J = 3.6 Hz, 10.0 Hz, H-3); 3.89 (t, 1H, J = 10.4 Hz, H-6); 3.78 (dt, 1H, J = 4.8 Hz, 9.2 Hz, H-5); 3.74 (d, 1H, J = 1.2 Hz, H-4'); 3.70 (dd, 1H, J = 3.2 Hz, 10.8 Hz, H-2'); 3.36 (s, 3H, OCH₃); 1.70 (d, 3H, J = 6.8 Hz, H-6'). ¹³C-APT NMR (100 MHz) δ: 138.2, 137.6, 137.5 (CH₆arom); 128.8, 128.5, 128.3, 128.2, 128.2, 128.1, 127.9, 127.9, 127.7, 127.6, 127.5, 126.1 (CH₆arom); 101.5 (PhCH); 98.8 (C-1); 97.3 (C-1'); 78.5 (C-4); 76.5 (C-2 or C-3'); 76.0 (C-4'); 75.0 (PhCH₂); 74.8 (C-3); 73.5 (C-2 or C-3'); 72.7, 71.9 (PhCH₂); 68.8 (C-6); 67.1 (C-5'); 64.1 (C-5); 58.9 (C-2'); 55.0 (OCH₃); 16.7 (C-6'). ¹³C-GATED (100 MHz) δ: 98.8 (C'H = 168 Hz, C-1); 97.3 (C'H = 170 Hz, C-1'). IR (thin film) ν: 2909, 2108, 1454, 1371, 1101, 1059, 1040, 1003. HRMS: [M+Na]⁺ calculated for C₄₄H₄₅N₇O₁₈Si: 746.30480; found 746.30475.
The title compounds (α/β 4:1) were obtained after size-exclusion chromatography (CH₂Cl₂/MeOH, 1:1 v/v), followed by column chromatography (toluene/acetone, 1:0 → 49:1 v/v), in 38% yield (29 mg, 0.038 mmol). ¹H NMR (400 MHz, for the α-isomer) δ: 8.12-8.09 (m, 2H, CH₂CH₂); 7.60-7.22 (m, 18H, CH₃); 5.72-5.69 (m, 2H, H-3', PhCH₂); 5.03 (d, 1H, J = 3.6 Hz, H-1'); 4.85 (d, 1H, J = 12.0 Hz, PhCH₂); 4.77 (d, 1H, J = 12.2 Hz, H-1); 4.71-4.65 (m, 2H, PhCH₂); 4.56 (q, 1H, J = 6.4 Hz, H-5'); 4.51 (d, 1H, J = 11.2 Hz, PhCH₂); 4.30-4.20 (m, H-4, H-6); 4.17 (dd, 1H, J = 1.6 Hz, 3.2 Hz, H-2); 3.98 (dd, 1H, J = 3.6 Hz, 10.2 Hz, H-3); 3.92-3.87 (m, 2H, H-4', H-6); 3.85-3.75 (m, 2H, H-2', H-5); 3.76 (s, 3H, OCH₃); 0.98 (d, 3H, J = 6.4 Hz, H-6'). Diagnostic peaks for the β-anomer: 5.62 (s, 0.25H, PhCH₂); 3.54 (q, 0.25H, J = 6.4 Hz, H-5'); 1.22 (d, 0.75H, J = 6.4 Hz, H-6'). ¹³C-APT NMR 100 MHz, for the α-isomer) δ: 165.8 (CO₂); 137.7, 137.4 (Cq arom); 135.5, 129.9 (CH₃ arom); 129.2 (Cq arom); 128.7, 128.5, 128.2, 128.1, 127.8, 127.6, 127.5, 127.3, 127.1, 126.0 (CH₃ arom); 101.4 (PhCH); 98.9 (C-1); 97.4 (C-1'); 78.8 (C-4); 77.5 (C-4'); 75.6 (PhCH₂); 74.6 (C-3); 74.3 (C-2); 73.0 (PhCH₂); 71.2 (C-3'); 68.7 (C-6); 66.7 (C-5'); 64.1 (C-5); 57.6 (C-2'); 54.9 (OCH₂); 16.1 (C-6'). IR (thin film) v: 2936, 2110, 1726, 1452, 1273, 1261, 1070, 1045, 1026, 1006. HRMS: [M+Na]⁺ calculated for C₄₁H₆₅N₅O₁₁Na: 774.26312; found 774.26333.

The title compound (α/β 10:1) was obtained after size-exclusion chromatography (CH₂Cl₂/MeOH, 1:1 v/v) and column chromatography (toluene/acetone, 1:0 → 49:1 v/v), in 58% yield (43 mg, 0.058 mmol). NMR data is reported for the α-isomer only. ¹H NMR (400 MHz) δ: 8.07-8.05 (m, 2H, CH₂CH₂); 7.58-7.25 (m, 18H, CH₃); 5.66 (s, 1H, PhCH₂); 5.65 (d, 1H, J = 2.4 Hz, H-4'); 5.03 (d, 1H, J = 3.2 Hz, H-1'); 4.88-4.80 (m, 2H, PhCH₂); 4.72 (d, 1H, J = 12.0 Hz, PhCH₂); 4.65 (q, 1H, J = 6.4 Hz, H-5'); 4.54 (d, 1H, J = 10.8 Hz, PhCH₂); 4.29-4.23 (m, 2H, H-6, H-3'); 4.20-4.15 (m, 2H,
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors

H-2, H-4): 4.02 (dd, 1H, \( j = 3.2 \) Hz, 10.0 Hz, H-3); 3.90 (t, 1H, \( j = 10.4 \) Hz, H-6); 3.80 (dt, 1H, \( j = 4.8 \) Hz, 9.6 Hz, H-5); 3.59 (dd, 1H, \( j = 3.6 \) Hz, 10.8 Hz, H-2'); 3.39 (s, 3H, \( \text{OC}_2H_3 \)); 1.04 (d, 3H, \( j = 6.8 \) Hz, H-6'). \(^{13}\)C-APT NMR (100 MHz) \( \delta \): 166.1 (CO\( _2H \)); 138.1, 137.6, 137.1 (C\( _{q,arom} \)); 133.2, 130.0, 129.8 (CH\( _{arom} \)); 129.6 (C\( _{q,arom} \)); 128.9, 128.4, 128.4, 128.3, 128.2, 128.2, 127.8, 127.8, 127.7, 127.1, 126.1 (CH\( _{arom} \)); 101.5 (C\( _{q,arom} \)); 98.8 (C-1); 97.3 (C-1'); 78.7 (C-2 or C-4); 74.5 (C-3); 74.2 (C-2 or C-4); 73.2 (C-3'); 73.1 (PhCH\( _2 \)); 71.3 (PhCH\( _2 \)); 69.8 (C-4'); 68.8 (C-6); 65.7 (C-5'); 64.1 (C-5); 58.7 (C-2'); 55.0 (OCH\( _3 \)); 16.2 (C-6'). IR (thin film) \( \nu \): 2932, 2108, 1721, 1452, 1373, 1267, 1175, 1101, 1074, 1061, 1045, 1026, 1003. HRMS: [M+Na\(^+ \)] calculated for C\( _{41}H_{48}N_3O_{10}Na \): 760.28407; found 760.28375.

Methyl 2-O-(2-azido-3-O-benzoyl-4-O-benzyl-2-deoxy-\( \alpha/\beta \)-L-fucopyranosyl)-3-O-benzyl-4,6-O-benzylidene-\( \alpha \)-D-mannopyranoside (\( \text{P4} \))

\(^1\)H NMR (400 MHz, for the \( \alpha \)-anomer) \( \delta \): 8.11 (d, 2H, \( j = 7.2 \) Hz, CH\( _{arom} \)); 7.60-7.22 (m, 18H, CH\( _{arom} \)); 5.72-5.69 (m, 2H, H-3', PhCH\( \_2 \)); 5.03 (d, 1H, \( j = 3.6 \) Hz, H-1'); 4.85 (d, 1H, \( j = 4.85 \) Hz, PhCH\( \_2 \)); 4.70 (d, 1H, \( j = 1.2 \) Hz, H-1); 4.70-4.65 (m, 2H, PhCH\( \_2 \)); 4.56 (q, 1H, \( j = 6.4 \) Hz, H-5'); 4.51 (d, 1H, \( j = 11.2 \) Hz, PhCH\( \_2 \)); 4.30-4.20 (m, 2H, H-4, H-6); 4.17 (dd, 1H, \( j = 1.6 \) Hz, 3.2 Hz, H-2); 3.98 (dd, 1H, \( j = 3.2 \) Hz, 10.2 Hz, H-3); 3.92-3.87 (m, 2H, H-4', H-6); 3.92-3.75 (m, 2H, H-2', H-5); 3.38 (s, 3H, OC\( \_2H_3 \)); 0.98 (d, 3H, \( j = 6.4 \) Hz, H-6'). Diagnostic peaks for the \( \beta \)-anomer: 5.62 (s, 0.25H, PhCH\( \_2 \)); 3.54 (q, 0.25H, \( j = 6.4 \) Hz, H-5'); 3.35 (s, 0.75H, OC\( \_2H_3 \)); 1.22 (d, 0.75H, \( j = 6.4 \) Hz, H-6'). \(^{13}\)C-APT NMR (100 MHz, for the \( \alpha \)-anomer) \( \delta \): 165.8 (CO\( _2H \)); 138.4, 137.7, 137.4 (C\( _{q,arom} \)); 133.5, 129.9 (CH\( _{arom} \)); 129.2 (C\( _{q,arom} \)); 128.8, 128.5, 128.2, 128.1, 127.8, 127.6, 127.5, 127.3, 127.1, 126.0 (CH\( _{arom} \)); 101.4 (PhCH\( \_2 \)); 98.9 (C-1); 97.4 (C-1'); 78.8 (C-4'); 77.5 (C-4'); 75.6 (PhCH\( \_2 \)); 74.6 (C-3); 74.3 (C-2); 73.0 (PhCH\( \_2 \)); 71.2 (C-3'); 68.7 (C-6); 66.7 (C-5'); 64.1 (C-5); 57.6 (C-2'); 54.9 (OCH\( _3 \)); 16.1 (C-6'). IR (thin film) \( \nu \): 2934, 2909, 2110, 1722, 1452, 1373, 1269, 1103, 1074, 1043, 1028. HRMS: [M+Na\(^+ \)] calculated for C\( _{41}H_{48}N_3O_{10}Na \): 760.28407; found 760.28375.
Chapter 3

*Methyl 2-O-(2-azido-2-deoxy-3,4-di-O-(tert-butylidimethylsilyl)-α-L-fucopyranosyl)-3-O-benzyl-4,6-O-benzylidene-α-D-mannopyranoside (F5)*

![Chemical Structure](image)

The title compound was obtained after column chromatography (hexane/Et₂O, 1:0 → 9:1) as the sole product in 67% yield (52 mg, 0.067 mmol). ¹H NMR (400 MHz) δ: 7.50-7.49 (m, 2H, CH₉); 7.39-7.25 (m, 13H, CH₉); 5.59 (s, 1H, PhCH); 4.95 (d, 1H, J = 3.6 Hz, H-1’); 4.80 (d, 1H, J = 12.4 Hz, PhCHH); 4.74-4.70 (m, 2H, H-1, PhCHF); 4.29-4.25 (m, H-5’, H-6’); 4.17 (dd, 1H, J = 2.4 Hz, 10.4 Hz, H-3’); 4.12-4.05 (m, H-2, H-4); 3.96 (dd, 1H, J = 3.2 Hz, 9.8 Hz, H-3); 3.86-3.76 (m, 2H, H-5, H-6); 3.71 (dd, 1H, J = 3.2 Hz, 10.4 Hz, H-2’); 3.61 (d, 1H, J = 1.6 Hz, H-4’); 3.36 (s, 3H, OC₃H₃); 1.01-0.99 (m, 12H, H-6’, (CH₃)₃Si); 0.91 (s, 9H, (CH₃)₃Si); 0.22, 0.16, 0.15, 0.14 (4x s, 3H, (CH₃)₂Si). ¹³C-APT NMR (100 MHz) δ: 138.4, 137.6 (C₉); 128.8, 128.3, 128.1, 127.5, 127.4, 126.1 (CH₉); 101.5 (PhCH); 99.1 (C-1); 79.0 (C-4); 75.3 (C-4’); 74.5 (C-3); 73.6 (C-2); 72.3 (PhCH₂); 70.9 (C-3’); 69.0 (C-6); 68.4 (C-5’); 64.0 (C-5); 60.9 (C-2’); 55.0 (OCH₃); 26.2, 26.1 ((CH₃)₃Si); 18.6, 18.6 (C₃Si); 17.2 (C-6’); -3.4, -3.4, -4.6, -4.7 (CH₃Si). IR (thin film) ν: 2930, 2857, 2108, 1254, 1177, 1103, 1061, 1042, 1028, 1004. HRMS: [M+Na]⁺ calculated for C₃₉H₆₁N₃O₆Si₂Na: 794.38385; found 794.38385.

*Methyl 2-O-(2-azido-4-O-benzyl-2-deoxy-3-O-(tert-butylidimethylsilyl)-α-L-fucopyranosyl)-3-O-benzyl-4,6-O-benzylidene-α-D-mannopyranoside (F6)*

![Chemical Structure](image)

The title disaccharide was isolated after column chromatography (hexane/Et₂O, 1:0 → 4:1) as the sole product in 74% yield (55 mg, 0.074 mmol). ¹H NMR (400 MHz) δ: 7.51-7.49 (m, 2H, CH₉); 7.40-7.24 (m, 13H, CH₉); 5.62 (s, 1H, PhCH); 5.00 (d, 1H, J = 11.2 Hz, PhCHH); 4.95 (d, 1H, J = 3.2 Hz, H-1’); 4.81-4.70 (m, 3H, H-1, PhCH₂); 4.53 (d, 1H, J = 11.2 Hz, PhCHH); 4.37 (q, 1H, J = 6.4 Hz, H-5’); 4.29-4.24 (m, 2H, H-3’, H-6’); 4.14-4.09 (m, 2H, H-2, H-4’); 3.97 (dd, 1H, J = 3.2 Hz, 10.0 Hz, H-3’); 3.86 (t, 1H, J = 10.4 Hz, H-6’); 3.78 (dt, 1H, J = 4.4 Hz, 9.6 Hz, H-5’); 3.64 (dd, 1H, J = 3.2 Hz, 10.4 Hz, H-2’); 3.44 (d, 1H, J = 2.4 Hz, H-4’); 3.36 (s, 3H, OC₃H₃); 1.04 (d, 3H, J = 6.4 Hz, H-6’); 0.99 (s, 9H, (CH₃)₃Si); 0.26 (s, 3H, CH₃Si); 0.21 (s, 3H, CH₃Si). ¹³C-APT NMR (100 MHz) δ: 138.6,
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors

138.3, 137.6 (C₉,arom); 128.8, 128.3, 128.2, 128.1, 127.8, 127.6, 127.5, 127.0, 126.1 (CH₂,arom); 101.5 (PhCH); 98.9 (C-1); 97.4 (C-1'); 81.0 (C-4'); 78.8 (C-4); 75.6 (PhCH₂); 74.6 (C-3); 73.5 (C-2); 72.5 (PhCH₂); 70.7 (C-3'); 68.9 (C-6); 67.1 (C-5'); 64.1 (C-5); 61.0 (C-2'); 55.0 (OCH₃); 25.8 ((CH₃)₃CSi); 18.1 (C₅Si); 16.6 (C-6'); -3.6, -5.0 (CH₃Si). IR (thin film) ν: 2928, 2857, 2106, 1454, 1371, 1258, 1171, 1101, 1040, 1004. HRMS: [M+Na]⁺ calculated for C₄₆H₅₃N₅O₉Si: 770.34433; found 770.34412.

Methyl 3-O-(2-azido-3,4-di-O-benzyl-2-deoxy-α-L-fucopyranosyl)-2-O-benzyl-4,6-O-benzylidene-α-D-mannopyranoside (G1)

The title compound was obtained after size-exclusion chromatography (CH₂Cl₂/MeOH, 1:1 v/v) and column chromatography (toluene/acetone, 1:0 → 9:1 v/v) in 72% yield (52 mg, 0.072 mmol).

¹H NMR (400 MHz) δ: 7.39-7.22 (m, 20H, CH₉,arom); 4.95-4.91 (m, 2H, H-1', PhCHH); 4.86 (d, 1H, J = 11.6 Hz, PhCHH); 4.72 (d, 1H, J = 12.0 Hz, PhCHH); 4.69-4.63 (m, 3H, H-1, PhCH₂); 4.53 (d, 1H, J = 11.6 Hz, PhCHH); 4.23 (dd, 1H, J = 4.0 Hz, 9.6 Hz, H-6); 4.16-4.09 (m, 3H, H-3, H-4, H-5'); 4.00 (m, 2H, H-2', H-3'); 3.88-3.77 (m, 3H, H-2, H-5, H-6); 3.56 (s, 1H, H-4'); 3.31 (s, 3H, OCH₃); 0.88 (d, 3H, J = 6.4 Hz, H-6'). ¹³C-APT NMR (100 MHz) δ: 138.3, 138.1, 137.7, 137.6 (C₉,arom); 128.9, 128.6, 128.4, 128.2, 128.1, 127.8, 127.6, 127.4, 126.2, 125.9 (CH₂,arom); 101.8 (PhCH); 100.3 (C-1); 95.7 (C-1'); 78.3 (C-3'); 77.1 (C-3 or C-4); 76.3 (C-4'); 75.4 (C-2); 74.8, 73.8 (PhCH₂); 73.4 (C-2); 72.1 (PhCH₂); 68.9 (C-6); 66.6 (C-5'); 64.2 (C-5); 59.9 (C-2'); 54.8 (OCH₃); 16.3 (C-6'). IR (thin film) ν: 2930, 2108, 1454, 1098, 1057, 1026. HRMS: [M+Na]⁺ calculated for C₄₅H₅₄N₅O₉Na: 746.30480; found 746.30414.

Methyl 3-O-(2-azido-3,4-di-O-benzoyl-2-deoxy-α-L-fucopyranosyl)-2-O-benzyl-4,6-O-benzylidene-α-D-mannopyranoside (G2)

The title compound was obtained after size-exclusion chromatography (CH₂Cl₂/MeOH, 1:1 v/v) and column chromatography (toluene/acetone, 1:0 → 49:1 v/v) in 64% yield (48 mg, 0.064
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mmol). $^1$H NMR (400 MHz) δ: 8.00-7.98 (m, 2H, $C_{H,arom}$); 7.90-7.87 (m, 2H, $C_{H,arom}$); 7.60-7.24 (m, 16H, $C_{H,arom}$); 5.79 (dd, 1H, $J = 3.2$ Hz, 10.0 Hz, H-3'); 5.64 (s, 1H, PhCH); 5.55 (d, 1H, $J = 2.0$ Hz, H-4'); 5.14 (d, 1H, $J = 3.6$ Hz, H-1'); 4.96 (d, 1H, $J = 12.0$ Hz, PhCH)$_2$; 4.78 (d, 1H, $J = 12.0$ Hz, PhCH$_2$H); 4.70 (d, 1H, $J = 1.6$ Hz, H-1); 4.57 (q, 1H, $J = 6.4$ Hz, H-5'); 4.27 (dd, 1H, $J = 4.4$ Hz, 9.6 Hz, H-6); 4.22-4.18 (m, 2H, H-3, H-4); 4.10 (dd, 1H, $J = 3.6$ Hz, 11.0 Hz, H-2'); 3.93-3.88 (m, 3H, H-2, H-5, H-6); 3.35 (s, 3H, OCH$_3$); 0.76 (d, 3H, $J = 6.4$ Hz, H-6'). $^{13}$C-APT NMR (100 MHz) δ: 165.7, 165.3 (C$_{arom}$); 138.1, 137.4 (C$_{arom}$); 133.3, 133.2, 129.7 (CH$_{arom}$); 129.5, 129.2 (C$_{arom}$); 129.1, 128.5, 128.4, 128.3, 128.2, 128.0, 127.7, 126.3 (CH$_{arom}$); 102.1 (PhCH); 100.4 (C-1); 96.3 (C-1') 77.1 (C-3 or C-4); 75.8 (C-2); 74.8 (C-3 or C-4); 73.9 (PhCH$_2$); 71.4 (C-4'); 70.1 (C-3'); 68.8 (C-6); 65.2 (C-5'); 64.4 (C-5); 58.8 (C-2'); 54.9 (OCH$_3$); 15.4 (C-6'). IR (thin film) ν: 2932, 2108, 1724, 1452, 1275, 1025, 771, 701, 692, 643, 628, 596, 549 (OCH$_3$); 15.8 (C-6'). HRMS: [M+Na]$^+$ calculated for C$_{41}$H$_{43}$N$_3$O$_{11}$Na: 774.2633; found 774.2629.

**Methyl 3-O-(2-azido-4-O-benzyl-3-O-benzyl-2-deoxy-α-L-fucopyranosyl)-2-O-benzyl-4,6-O-benzylidene-α-D-mannopyanoside (G3)**

The title compound was obtained after size-exclusion chromatography (CH$_2$Cl$_2$/MeOH, 1:1 v/v) and column chromatography (toluene/acetone, 1:0 → 49:1 v/v) in 54% yield (40 mg, 0.054 mmol). $^1$H NMR (400 MHz) δ: 8.08-8.06 (m, 2H, $C_{H,arom}$); 7.61-7.59 (m, 1H, $C_{H,arom}$); 7.47-7.19 (m, 17H, $C_{H,arom}$); 5.59 (s, 1H, PhCH); 5.52 (d, 1H, $J = 2.8$ Hz, H-4'); 5.02 (d, 1H, $J = 3.6$ Hz, H-1'); 4.94 (d, 1H, $J = 11.6$ Hz, PhCH$_2$H); 4.81-4.75 (m, 2H, PhCH$_2$); 4.68 (d, 1H, $J = 1.2$ Hz, H-1); 4.50 (d, 1H, $J = 10.8$ Hz, PhCH$_2$H); 4.41 (q, 1H, $J = 6.4$ Hz, H-5'); 4.25 (dd, 1H, $J = 3.6$ Hz, 9.4 Hz, H-6); 4.17-4.12 (m, H-3, H-4, H-3'); 3.91-3.80 (m, 4H, H-2, H-5, H-6, H-2'); 3.33 (s, 3H, OCH$_3$); 0.83 (d, 3H, $J = 6.4$ Hz, H-6'). $^{13}$C-APT NMR (100 MHz) δ: 166.1 (CO$_2$H); 138.1, 137.6, 137.1 (C$_{arom}$); 133.2, 129.8 (CH$_{arom}$); 129.7 (C$_{arom}$); 129.2, 128.4, 128.3, 128.3, 128.1, 127.8, 127.8, 26.2 (CH$_{arom}$); 102.1 (PhCH); 100.4 (C-1); 96.0 (C-1'); 77.1, 75.6, 75.0, 74.2 (C-2, C-3, C-4, C-3'); 73.8, 71.4 (PhCH$_2$); 70.0 (C-4'); 68.9 (C-6); 65.2 (C-5'); 64.3 (C-5); 59.6 (C-2'); 54.9 (OCH$_3$); 15.8 (C-6'). IR (thin film) ν: 2930, 2110, 1721, 1454, 1269, 1110, 1099, 1059, 1026, 1003. HRMS: [M+Na]$^+$ calculated for C$_{41}$H$_{43}$N$_3$O$_{11}$: 760.28407; found 760.28387.
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors

*Methyl 3-O-(2-azido-3-O-benzoyl-4-O-benzyl-2-deoxy-α/β-L-fucopyranosyl)-2-O-benzyl-4,6-O-benzylidene-α-D-mannopyranoside (G4)*

![Structural formula of G4]

The products (α/β 10:1) were obtained after size-exclusion chromatography (CH$_2$Cl$_2$/MeOH, 1:1 v/v) and column chromatography (toluene/acetone, 1:0 → 49:1 v/v) in 64% yield (47 mg, 0.064 mmol). $^1$H NMR (400 MHz) δ: 8.08-8.06 (m, 2H, CH$_{arom}$); 7.61-7.17 (m, 18H, CH$_{arom}$); 5.61-5.57 (m, 2H, H-3', PhCH$_2$); 5.03 (d, 1H, J = 3.6 Hz, H-1'); 4.93 (d, 1H, J = 12.0 Hz, PhCHH); 4.73 (d, 1H, J = 12.0 Hz, PhCHH); 4.66 (d, 1H, J = 1.6 Hz, H-1); 4.58 (d, 1H, J = 11.2 Hz, PhCHH); 4.46 (d, 1H, J = 11.2 Hz, PhCHH); 4.32 (q, 1H, J = 6.4 Hz, H-5'); 4.25 (dd, 1H, J = 4.0 Hz, 9.8 Hz, H-6); 4.21-4.13 (m, 3H, H-3, H-4, H-2'); 3.88 (t, 1H, J = 10.0 Hz, H-6); 3.83-3.78 (m, 3H, H-2, H-5, H-4'); 3.32 (s, 3H, OCH$_3$); 0.82 (d, 3H, J = 6.4 Hz, H-6'). $^{13}$C-APT NMR (100 MHz) δ: 165.8 (CO$_2$H); 138.1, 137.6 (C$_{arom}$); 133.5, 129.8 (CH$_{arom}$); 129.3 (C$_{arom}$); 128.9, 128.7, 128.5, 128.3, 128.2, 128.1, 128.0, 127.8, 127.7 (CH$_{arom}$); 102.0 (PhCH); 100.4 (C-1'); 96.2 (C-1'); 77.5 77.1, 75.7, 74.2 (C-2, C-3, C-4, C-4'); 75.6, 73.8 (PhCH$_2$); 73.0 (C-3'); 68.8 (C-6); 66.4 (C-5'); 64.3 (C-5); 58.8 (C-2'); 54.8 (OCH$_3$); 15.8 (C-6'). IR (thin film) ν: 2932, 2108, 1722, 1452, 129, 1098, 1067, 1026. [M+Na]$^+$ calculated for C$_{41}$H$_{43}$N$_3$O$_{10}$: 760.28407; found 760.28357.

*Methyl 3-O-(2-azido-2-deoxy-3,4-di-O-(tert-butyldimethylsilyl)-α/β-L-fucopyranosyl)-2-O-benzyl-4,6-O-benzylidene-α-D-mannopyranoside (G5)*

![Structural formula of G5]

The title product was obtained after column chromatography (hexane/Et$_2$O, 1:0 → 4:1) in 73% yield (56 mg, 0.073 mmol). $^1$H NMR (400 MHz) δ: 7.45-7.25 (m, 10H, CH$_{arom}$); 5.58 (s, 1H, PhCH$_2$); 4.98-4.95 (m, 2H, H-1, PhCH$_2$H); 4.78 (d, 1H, J = 11.6 Hz, PhCH$_2$H); 4.69 (d, 1H, J = 1.6 Hz, H-1); 4.24 (dd, 1H, J = 4.0 Hz, 9.6 Hz, H-6); 4.14-4.12 (m, 2H, H-3, H-4); 4.07-4.02 (m, 2H, H-3', H-5'); 3.88-3.82 (m, H-2, H-2', H-5, H-6); 3.55 (d, 1H, J = 1.6 Hz, H-4'); 3.32 (s, 3H, OCH$_3$); 0.94 (s, 9H, (CH$_3$)$_3$SiO); 0.90 (s, 9H, (CH$_3$)$_3$SiO); 0.79 (d, 3H, J = 6.4 Hz, H-6'); 0.16, 0.13, 0.13, 0.03 (4x s, 3H, CH$_3$SiO). $^{13}$C-APT NMR (100 MHz) δ: 138.4, 137.8 (C$_{arom}$); 128.9, 128.3, 128.1, 127.9, 127.7, 126.2, 125.8 (CH$_{arom}$); 101.9 (PhCH$_2$); 100.7 (C-1); 96.1 (C-1'); 77.3 (C-3, C-4); 75.7 (C-2, C-5); 75.3 (C-4'); 73.9 (C-3, C-4); 73.9 (PhCH$_2$); 71.4 (C-3', C-5'); 68.9 (C-6); 68.0 (C-3', C-5'); 64.4 (C-2, C-5); 61.4 (C-6').
The title compounds (α/β 10:1) were obtained after column chromatography (hexane/Et₂O, 1:0 → 4:1) in 64% yield (48 mg, 0.064 mmol). NMR data is reported for the α-isomer only. ¹H NMR (400 MHz) δ: 7.46-7.24 (m, 15H, CH₃; 5.58 (s, 1H, PhCH₂); 5.00-4.92 (m, 3H, H-1', 2x PhCHH); 4.78 (d, 1H, / = 11.6 Hz, PhCH₂); 4.70 (d, 1H, / = 1.6 Hz, H-1); 4.50 (d, 1H, / = 10.8 Hz, PhCHH); 4.42 (dd, 1H, / = 4.0 Hz, 9.6 Hz, H-6); 4.16-4.06 (m, 4H, H-3, H-3’, H-4, H-5’); 3.90 (dd, 1H, / = 3.2 Hz, 10.2 Hz, H-2’); 3.88-3.79 (m, 3H, H-2, H-5, H-6); 3.36-3.32 (m, 4H, H-4’, OCH₂); 0.96 (s, 9H, (CH₃)₃Si); 0.80 (d, 3H, / = 6.4 Hz, H-6’); 0.21 (s, 3H, C₃H₇Si); 0.15 (s, 3H, C₃H₇Si). ¹³CAPT NMR (100 MHz) δ: 138.7, 138.3, 137.7 (CH₃; 128.9, 128.6, 128.4, 128.2, 128.1, 128.0, 127.9, 127.8, 127.7, 127.5, 127.4, 126.2, 125.8 (CH₃); 101.9 (PhCH); 100.5 (C-1); 96.5 (C-1’); 81.0 (C-4’); 77.2 (C-4); 75.8 (C-2); 75.6 (PhCH₂); 74.4 (C-3 or C-3’); 73.8 (PhCH₂); 71.8 (C-3 or C-3’); 68.9 (C-6); 66.9 (C-5’); 63.3 (C-5); 62.3 (C-2’); 54.8 (OCH₂); 25.9 ((CH₃)₃Si); 18.0 (C₃Si); 16.1 (C-6’); -4.2, -5.0 (CH₃Si). IR (thin film) v: 2930, 2857, 2106, 1454, 1364, 1260, 1117, 1098, 1047, 1028. HRMS: [M+Na]⁺ calculated for C₄₀H₃₅N₃O₅Si: 770.34433; found 770.34424.
Reactivity and selectivity of 2-azido-2-deoxy-fucosyl donors


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