Selenium-Containing Glycosides and Glycosyl Phosphates as Precursors of Glycosyl Epoxides: New Approaches to the Synthesis of (5-Fluoro) and (5-Cyano) Glycosides

by

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"Although we have now learned to synthesize oligosaccharides, it should be emphasized that each oligosaccharide synthesis remains an independent problem, whose resolution requires considerable systematic research and a good deal of know-how. **There are no universal reaction conditions for oligosaccharide synthesis.**"

Hans Paulsen, quoted in *Eur. J. Org. Chem*. **2004**, 1387-1395.

To My Family

For all of your love and support over the years

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LIST OF ABBREVIATIONS

(5-F)-GalNAcOR	(5-Fluoro) *N*-Acetylgalactosamine-O-glycoside
(5-F)-GlcNAcOR	(5-Fluoro) *N*-Acetylglucosamine-O-glycoside
AcBr	Acetyl bromide
Ac_2O	Acetic Anhydride
$BF_3 \cdot OEt_2$	Boron trifluoride etherate
Bn	Benzyl
BOM	Benzyloxymethyl
Bz	Benzoyl
CH_2Cl_2	Methylene Chloride
CH_3CN	Acetonitrile
DAST	Diethylamino sulfurtrifluoride
DHP	3, 4-Dihydro-2*H*-pyran
DIEA	*N*, *N*-Diisopropylethylamine
DMDO	Dimethyldioxirane
DMF	Dimethylformamide
DMSO	Dimethylsulfoxide
ESI	Electrospray Ionization
FucT III	α-1, 3/1,4-Fucosyltransferase
Gal	Galactose
GalNAc	*N*-Acetylgalactosamine
GalNAcOR	*N*-Acetylgalactosamine-O-glycoside
GalNAcT	*N*-Acetylgalactosaminyltransferase
GalT	Galactosyltransferase
GDP-Fuc	Guanidine 5'-diphospho-fucose

GDP-Gal	Guanidine 5'-diphospho-galactose
GlcNAc	*N*-Acetylglucosamine
GlcNAcOR	*N*-Acetylglucosamine-O-glycoside
Gluco	Glucopyranose
HRMS	High Resolution Mass Spectrometry
isoLacNAc	*N*-Acetylisolactosamine
k_{cat}	Rate of catalysis
k_{cat}/K_M	Catalytic Efficiency
K_M	Rate of binding
LacNAc	*N*-Acetyllactosamine
LDA	Lithium diisopropylamine
MeOH	Methanol
MS	Mass Spectrometry
NaOMe	Sodium Methoxide
NBS	*N*-Bromosuccinimide
NEt_4OAc	Tetraethylammonium acetate
NBu_4I	Tetrabutylammonium iodide
NEt_3	Triethylamine
NMR	Nuclear Magnetic Resonance
OAc	Acetate
Ph	Phenyl
Pht	Phthaloyl
PMP	*p*-Methoxyphenyl
Pyr	Pyridine
TBS	*t*-Butyldimethylsilyl
Tf	Trifluoromethanesulfonyl
TFA	Trifluoroacetate
TFAA	Trifluoroacetic Anhydride
Tf_2O	Trifluoromethanesulfonic Anhydride
THF	Tetrahydrofuran
TLC	Thin Layer Chromatography

Tol	Toluene
Troc	Trichloroethoxycarbonyl
TsOH	*p*-Toluenesulfonic Acid
TTBP	Tetrabenzylpyrophosphate
UDP	Uridine 5'-diphospho
UDP-Gal	Uridine 5'-diphospho-galactose
UDP-GalNAc	Uridine 5'-diphospho-*N*-Acetyl-galactosamine
UDP-(5-F)-GalNAc	Uridine 5'-diphospho-(5-Fluoro) *N*-acetyl-galactosamine
UDP-GlcNAc	Uridine 5'-diphospho-*N*-acetyl-glucosamine
UDP-(5-F)-GlcNAc	Uridine 5'-diphospho-(5-Fluoro) *N*-acetyl-glucosamine

ABSTRACT

Enzyme-catalyzed transformations of carbohydrates proceed through different transition states, which may be studied by altering the electron density at various positions of the carbohydrate ring. By placing fluorine near a developing partial charge of a donor substrate, the reaction may be inhibited due to destabilization of the transition state. The pK_a of an acceptor alcohol is also lowered by fluorine, possibly affecting its nucleophilicity. Epoxide fluoridolysis has been previously used in our lab to synthesize (5-F) GlcNAc glycosides and glycosyl phosphates. This methodology involves a two-step process of oxidation of a phenylselenide to a selenoxide and thermal elimination with DHP. This thesis extends this fluoridolysis methodology to (5-F) isoLacNAc and (5-F) LacNAc glycosides and also investigates fluorination in the GalNAc series. Results from attempts at fluorination of the GalNAc glycosides have resulted in a premature epoxide opening hypothesis. This hypothesis was derived from differences in fluorination of glycosyl epoxides containing different neighboring protecting groups.

In the pursuit of the (iso)LacNAc glycosides, selenium-containing monosaccharide acceptor substrates were unsuccessful in glycoside formation. In contrast, glycosylation of non-selenium containing monosaccharide acceptor substrates were successful in glycoside formation and were converted to selenium-containing disaccharides after glycosylation. The resulting selenium-containing disaccharides were then transformed into their corresponding epoxides and eventually into (5-F) isoLacNAc and (5-F) LacNAc glycosides.

In addition to studying fluorinated glycosides, formation of a new stable C-C bond has been investigated. This new transformation would increase functionality on the carbohydrate ring by installing a CN group at C-5. The CN group was installed using a Lewis acid activator and TMS-CN in cyanosilylation of glycosyl epoxides. This new method allows for subsequent reduction of the CN functional group to an amine, which could then be transformed into a probe of carbohydrate metabolizing enzymes.

CHAPTER 1

INTRODUCTION

Complex carbohydrates are important components of biological pathways and systems, such as blood group antigens, cellular metabolism, intercellular communication, and other processes.[1] These carbohydrates are involved in glycoconjugates, such as glycoproteins and glycolipids, which are found in cell walls of bacteria, in cellular adhesion and other sites in various biological systems. The numbering system established for hexopyranoses is shown in Figure 1.1 for D-glucose. Carbon 1 is referred to as the anomeric position, and in the reducing sugar form (as shown in Figure 1.1), the carbohydrate exists in both the open (aldohexose) and closed (hexopyranose or hexofuranose) forms of the carbohydrate ring. C-1 of hexopyranosides determines the type of linkage in a glycosidic bond, where the C-1 substituent below the plane of the pyranose is an α-linkage and a substituent above the plane the pyranose is a β-linkage.[2]

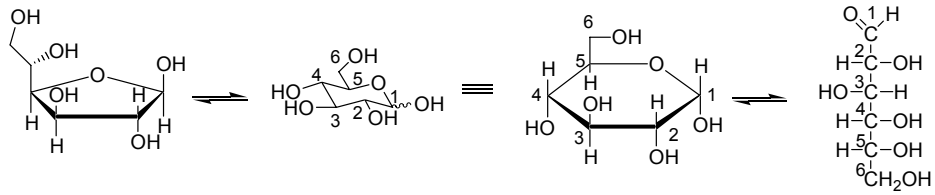


Figure 1.1: Numbering for Hexopyranoses

Biosynthesis of complex carbohydrates involves several classes of enzymes, such as transferases, epimerases, dehydrogenases, oxidases and pyrophosphorylases. A glycosylation reaction between two carbohydrates involves an acceptor, which serves as the nucleophile, and the anomeric position of a donor, which serves as the electrophile. An example of an enzyme-catalyzed glycosylation reaction of glucose by UDP-galactose catalyzed by lactose synthase (E.C. 2.4.1.22) is shown in Figure 1.2.[3]

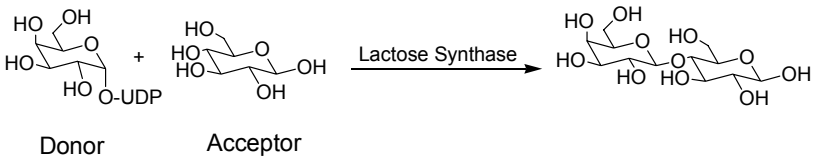


Figure 1.2: Example of a Glycosyltransferase Reaction

Enzyme-catalyzed transformations of carbohydrates proceed through transition states, which may be studied by altering the electron density at various positions of the carbohydrate ring. A glycosylation reaction may be considered a nucleophilic substitution reaction in that loss of a leaving group and subsequent replacement by the nucleophile is observed. The degree of bond formation and bond breaking in the transition state is represented in Figure 1.3. A dissociative (exploded) transition state is characterized by formation of an oxocarbenium ion resulting from loss of the leaving group on the donor substrate and then nucleophilic attack by the acceptor substrate (Figure 1.3A). In an associative transition state, there are shorter bonds associated with the loss of the leaving group and new bond formation by the nucleophile (Figure 1.3B).

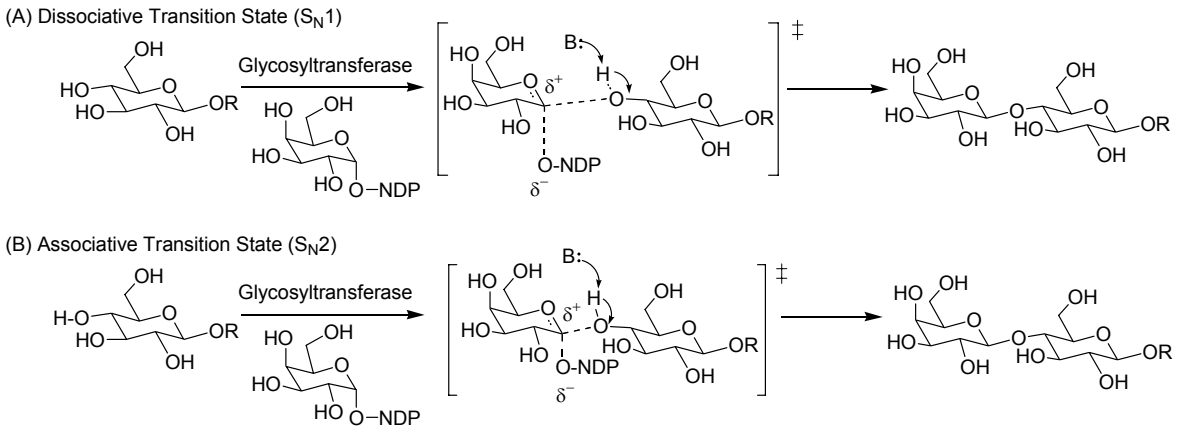


Figure 1.3: Dissociative vs. Associative Transition States

By placing fluorine near a developing partial positive charge in the transition state, the reaction may be inhibited due to destabilization of the transition state. The pK_a of the proximal alcohol in the acceptor substrate is also lowered, possibly affecting its nucleophilicity (Figure 1.4). The amount of inhibition by fluorine on the glycosylation reactions of interest will provide data towards the mechanism of action (dissociative vs. associative) of the enzyme.

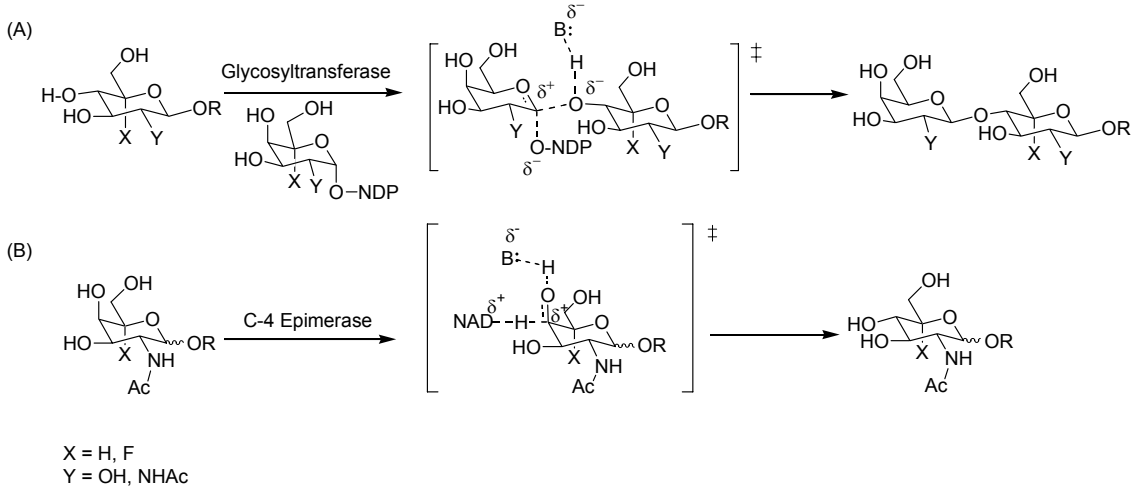


Figure 1.4: Proposed Transition States

Fluorine is an attractive choice for probing the transition state because of its strong electron-withdrawing characteristic, yet minimal steric effect (Table 1.1).[4] The size of a C-F bond is similar to a C-OH bond and fluorine is a common choice for replacing C-OH groups to study carbohydrate metabolizing enzymes. These fluorinated deoxy sugars have been used to evaluate enzyme recognition of substrates by changing the hydrogen-bonding network from a donor (OH) to an acceptor (F).[5] Replacement of a hydroxyl group with fluorine can be accomplished in one-step using DAST (diethylaminosulfur trifluoride)[6] or Selectflour[7].

Table 1.1: Comparison of Fluorine with Hydrogen and OH Bonds

Element	Bond Length CH_3-X (Å)	Van der Waals Radius (Å)	Total (Bond Length and Van der Waals Radius) (Å)	Electronegativity of H, F, and O
H	1.09	1.20	2.29	2.1
F	1.39	1.35	2.74	4.0
O (in OH)	1.43	1.40	2.83	3.5

A more difficult transformation to obtain is the replacement of a C-H bond with a C-F bond. Fluoridolysis usually requires multiple synthetic transformations (as described later). Additionally, having fluorine at C-5 may lead instability because it is adjacent to the carbohydrate ring oxygen. Donation of the lone pair of the ring oxygen may lead to loss of fluoride ion and formation of an oxocarbenium ion (Figure 1.5).

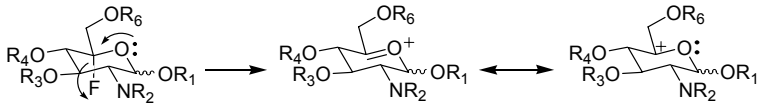


Figure 1.5: Formation of Oxocarbenium Ion from Loss of Fluoride

Previous attempts at forming C-5 carbon-fluorine bonds in carbohydrates have resulted in poor yields (Figure 1.6). In the radical halogen exchange method developed by Withers and coworkers,[9] compound **1** was brominated with NBS to form a C-5 bromide. The bromide was then displaced and epimerized with silver fluoride to give **2** in a poor yield of 8% (2 steps). Compound **2** had its remaining protecting groups removed using methanolic ammonia to form **3**. The (5-F) glycoside was then used as a mechanistic probe of carbohydrate metabolizing enzymes.[9,10]

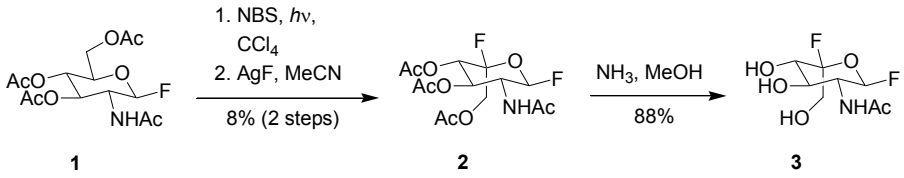
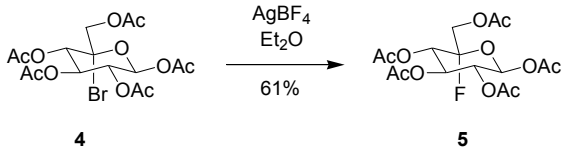


Figure 1.6: Radical Halogenation at C-5 by Withers and Coworkers

In addition to the displacement of bromide with AgF (Figure 1.5), White and coworkers improved the radical halogenation method by using $AgBF_4$ to form the C-F bond at C-5 (Figure 1.7).[11] The known compound **4**[12] was fluorinated with $AgBF_4$ to give **5** in 61% yield.



4 **5**

Figure 1.7: Radical Halogenation at C-5 by White and Coworkers

Substitution of fluorine at the C-5 position in the synthesis of 5-fluoro derivatives of *N*-acetylglucosamine (GlcNAc) is also achieved using the epoxide fluoridolysis methodology previously developed in our lab (Figure 1.8).[8] A 5, 6-epoxide (**8** or **10**) is opened with HF·pyridine to install the desired C-F bond at C-5. A phenylselenide at C-6 (**6**) is oxidized and eliminated in a two-step process to form an olefin (**7** or **9**), which is oxidized to yield the desired 5, 6-epoxide. Fluoridolysis in the GlcNAc series proceeds in good yields (72-83%) and the epoxide intermediates are useful substrates for other nucleophilic reactions at C-5. However, epoxide fluoridolysis has not been reported in the GalNAc or (iso)LacNAc series and will be applied to these carbohydrates. In addition to fluoridolysis, acid-catalyzed reactions of hindered 2, 3 glycosyl epoxides are attained with TMS-CN or HCN and a Lewis acid.[13-16] Acid-catalyzed "C-glycosylation" has not been applied to the 5, 6 GlcNAc epoxide **8** (X = OH, Y = H, Z = OH) and will be attempted in the GlcNAc series. The epoxides **8** and **10** are key intermediates because of the various possibilities of glycosylation reactions available.

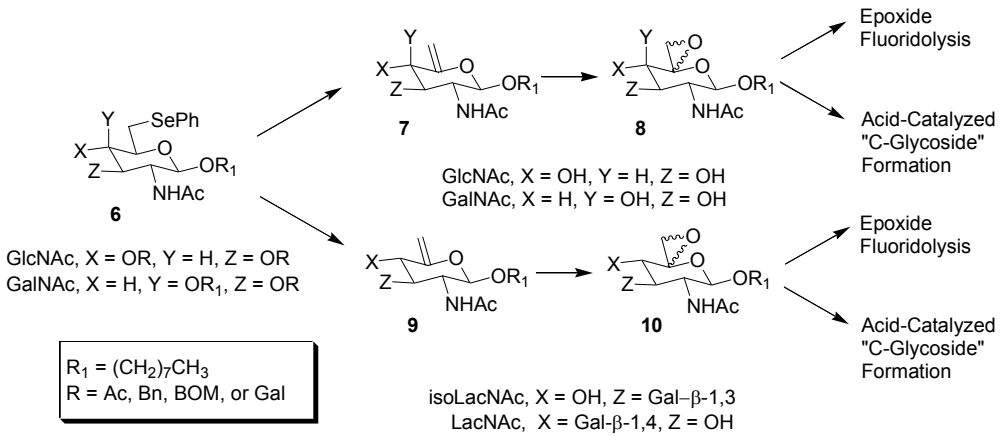


Figure 1.8: Epoxide Glycosylation Methodologies

Epoxide fluoridolysis has proven successful in the GlcNAc series (X = OH, Y = H, Z = OH). (5-F)-GlcNAc-β-octyl glycoside was synthesized and evaluated as an alternate acceptor substrate for β-1, 4 GalT (EC 2.4.1.38) from bovine milk. Results shows there was minimal effect on the k_{cat} of the reaction for the fluorinated versus non-fluorinated substrates, suggesting little bond formation between the acceptor and the UDP-Gal donor (Table 1.2 and Figure 1.9).[17] This result supports a dissociative transition state, which contains minimal bond formation between an acceptor and a donor. If negligible bond formation between an acceptor and the donor is observed, an oxocarbenium ion intermediate resulting from a more significant bond dissociation of the leaving group (UDP) similar to an S_N1 type reaction is suggested.

Table 1.2: Comparison of β-1, 4 GalT octyl-GlcNAc Glycoside versus (5-F) Octyl-GlcNAc Kinetic Data

Substrate	K_M^{app}	k_{cat}^{app}	k_{cat}/K_M
	(μM)	(s-1)	($M^{-1}s^{-1}$)
octylGlcNAc	52 ± 4	9.1 ± 0.5	175, 000
Octyl(5-F)GlcNAc	295 ± 65	6.5 ± 0.6	21, 700

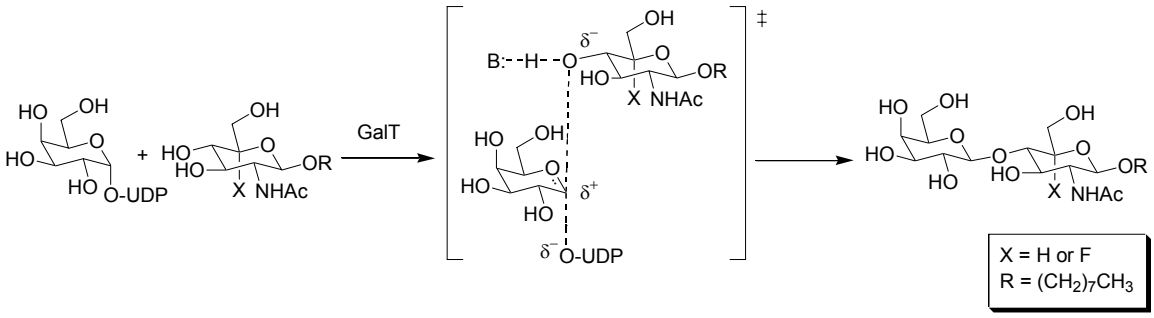


Figure 1.9: β-1, 4 GalT Transition State

In addition, the epoxide fluoridolysis methodology was successful in the synthesis of the donor UDP-(5-F)-GlcNAc. UDP-(5-F)-GlcNAc was studied with CLS (UDP-GlcNAc:GlcNAc-P-P-Dol *N*-acetylglucosaminyltransferase, EC 2.4.1.141).[17] UDP-GlcNAc had a K_m of 392 ± 83 μM and a V_{max} of 27.5 ± 1.9 cpm/min/μg. However, UDP-(5-F)-GlcNAc was inactive as a donor for CLS, suggesting UDP-(5-F)-GlcNAc to be an inhibitor. Figure 1.10 indicates that UDP-(5-F)-GlcNAc at 1.5 mM and 0.25 mM concentrations acted as an inhibitor when increasing the amount of UDP-GlcNAc. For both concentrations, increasing the concentration of UDP-GlcNAc lowers the inhibition of UDP-(5-F)-GlcNAc. The data suggests that the fluorinated donor served as a competitive inhibitor of UDP-GlcNAc and not as a substrate (Figure 1.10).[17] The

inactivating effect gives evidence that the electron-withdrawing fluorine is destabilizing a forming oxocarbenium ion-like transition state.

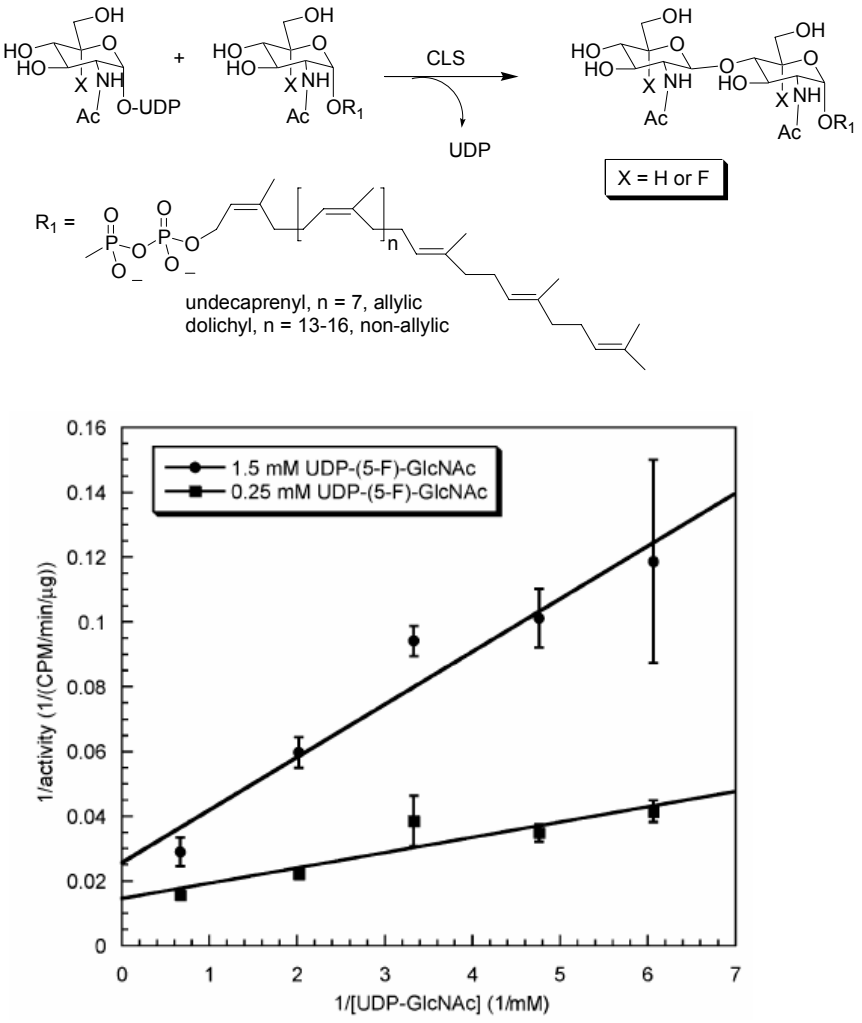


Figure 1.10: Inhibition Studies of CLS by UDP-(5-F)-GlcNAc

The UDP-(5-F)-GlcNAc alternate substrate was also evaluated as a mechanistic probe with UDP-GlcNAc C-4 epimerase. UDP-GlcNAc C-4 epimerase is found within the biosynthetic pathway of an unusual carbohydrate found in the lipopolysaccharide of the waterborne pathogen, *Plesiomonas shigelloides*.[18] The enzyme catalyzes the

epimerization of the C-4 hydroxyl group of UDP-GlcNAc to UDP-GalNAc resulting in a 70:30 equilibrium, favoring UDP-GlcNAc (Figure 1.11). UDP-(5-F)-GlcNAc was shown to be an alternate substrate for the epimerase with a 270-fold decrease in k_{cat} (Table 1.3).[19] The decrease in k_{cat}/K_m may be due to the 5-fluoro group hindering the rotation about the C-O-P bond during catalysis or due to the 5-fluoro group destabilizing the putative positive charge formation during hydride abstraction (Figure 1.11). More experimental data are needed in order to determine which mode of inhibition is occurring.

Table 1.3: Comparison of UDP-C-4-Epimerase UDP-GlcNAc versus UDP (5-F) GlcNAc Kinetic Data

Substrate	K_M (μM)	k_{cat} (min^{-1})	k_{cat}/K_M ($M^{-1}s^{-1}$)
UDP-GlcNAc[18]	137 ± 17	461 ± 33	56100 ± 403
UDP-(5-F)-GlcNAc	5.6 ± 1.7	1.73 ± 0.12	5100

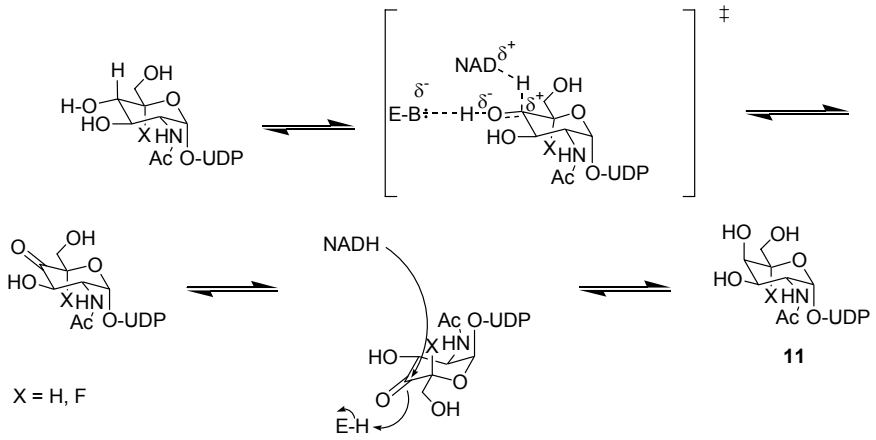


Figure 1.11: Reaction Catalyzed by UDP-GlcNAc C-4 Epimerase: Proposed Mechanism

An extension of the epoxide fluoridolysis methodology is to study the effects of fluorine in the galactosamine (GalNAc) series (Figure 1.8). Since there was no genuine

sample of the UDP-(5-F)-GalNAc, **11**, available at the time of the C-4 epimerase research described above, **11** was selected as a synthetic target. This sugar nucleotide could also be evaluated as a substrate for the C-4 epimerase and used as a mechanistic probe for GalNAcT in *O*-glycan biosynthesis (Figure 1.12A).

The biosynthesis of *O*-glycans, such as, Core 1 and Core 2, plays an important role in cellular adhesion, differentiation, invasion and metathesis of tumors.[20] Recently, a positive correlation between increased GalNAcT activity and invasion and metathesis in early stages of gastric cancer has been reported (Figure 1.12A).[21] Compound **11** could be used to determine the effects of fluorine on the donor substrate of GalNAcT and could potentially inhibit the formation of the Core 1 and Core 2 biosynthetic products involved in tumor progression of gastric cancer. Additionally, the effects of fluorine on an acceptor substrate in O-glycan biosynthesis, could also be investigated by synthesizing **12** as a possible β-1, 4 GalT substrate (Figure 1.12B). β-1, 4 GalT utilizes the acceptor *O*-linked glycopeptide, **12**, and the donor GDP-Gal in order to form the Core 1 and Core 2 products. By inhibiting the β-1, 4 GalT enzymatic reaction, the Core products may be decreased and therefore result in a reduction of tumor progression. Based upon previous results, it is expected that the donor UDP-(5-F)-GalNAc should have a greater effect on *O*-glycan biosynthesis than the acceptor (5-F)-GlcNAc-β-octyl glycoside.

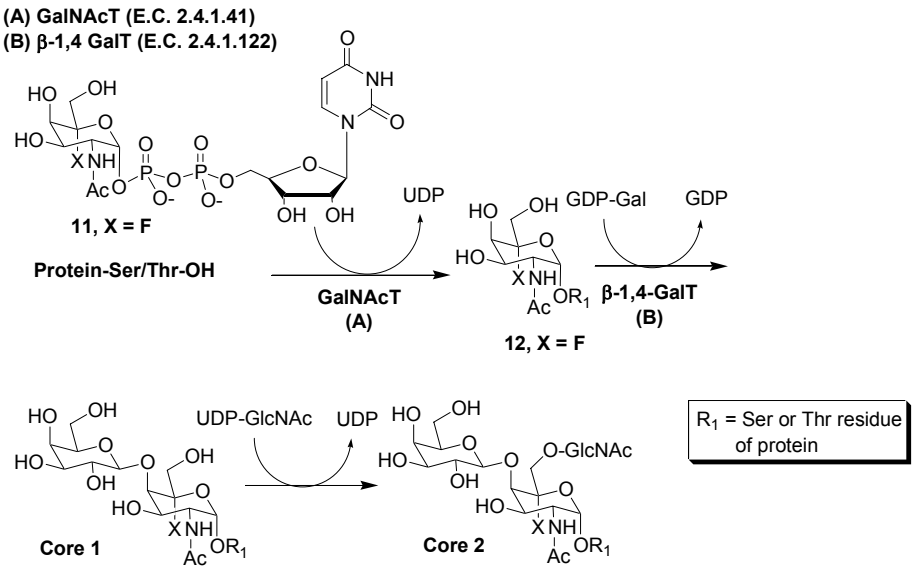


Figure 1.12: Reactions catalyzed by (A) GalNAcT and (B) β-1, 4 GalT

As well as studying the effects of fluorine on both donor and acceptor substrates in the *O*-glycan biosynthetic pathway, the proximity effect of fluorine could be investigated. FucT III (E.C. 2.4.1.65), involved in Lewis B blood group antigens, fucosylates the free C-4 or C-3 hydroxyl groups of the two disaccharides type 1 (isoLacNAc) and type 2 (LacNAc), respectively (Figure 1.13).[22] FucT III has been linked to an increase in tumor size in prostate cancer cell line PC-3 due to an increase in cellular adhesion in the stromal cells.[23] Therefore, work towards the inhibition of this enzyme could potentially impede prostate cancer progression. Two fluorinated analogs, **13a** and **14a**, could aid in investigating the effects of fluorine on FucT III glycosyl acceptor substrates by differentially affecting the pK_a of the C-4 hydroxyl versus the C-3 hydroxyl and potentially affect their ability to act as acceptor substrates. It is also necessary to synthesize **13b** and **14b** in order to have non-fluorinated control substrates as the octyl glycoside ($R = (CH_2)_7CH_3$) is not the natural substrate for the enzyme. The octyl chain is

necessary for the binding to a reverse-phase solid support in the Sep-Pak assay used to evaluate the enzymatic reaction.[24] The octyl side chain adheres to the reverse-phase C-18 column and elution with water results in water-soluble impurities in the column fractions. The desired octyl glycosides remain on the column, as they are not water soluble. The resulting glycosides are then eluted using MeOH. The effect of fluorine on FucT III could be analyzed by comparing the rates of **13a** and **14a** to **13b** and **14b**, respectively. If FucT III follows a dissociative transition state similar to the β-1, 4 GalT, then there should be minimal difference between **13a** and **14a** as there should be little bond formation between the acceptor substrate and the GDP-Fuc donor. The ability of **13a** and/or **14a** to act as substrates in FucT III catalyzed glycosylation would permit the incorporation of fluorine in semisynthetic neoglycoconjugates.

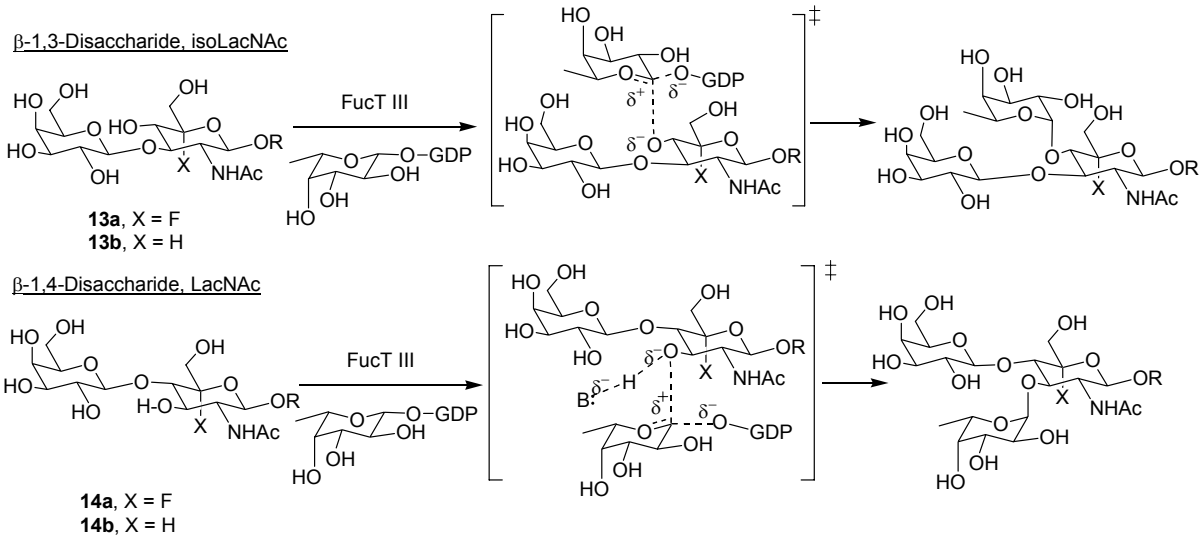


Figure 1.13: Proposed Transition States for FucT III

In addition to epoxide fluoridolysis, it is possible that 5, 6 epoxides (Figure 1.8) could be used to form novel C-glycosides (Figure 1.14). It is known that 2, 3 epoxides can be converted to cyanodeoxy sugars. Regioisomers **16** and **17** can be formed from the 2, 3 epoxide **15** with either HCN[16] or TMS-CN[14] and a Lewis acid. Currently, there are no 5, 6 glycosyl epoxides reported using this type of acid-catalyzed "C-glycosylation". The reaction conditions effective for acid-catalyzed C-glycosylation of 2, 3 epoxides **15** and **18** will be attempted on the 5, 6 epoxides, **19** (Figure 1.15). Formation of the (5-cyano) sugars would broaden the ability to functionalize carbohydrates. A stable C-C bond C-5 could be reduced to an amine, leading to branching of sugars or greater functionalization of glycosides (Figure 1.15). In addition, formation of the free amine **22** could be useful as a probe for carbohydrate metabolizing enzymes. A biotin molecule may be attached to the amine and used in a biotin/avidin capture assay[25] as a new method for evaluating glycosyltranferase reactions.

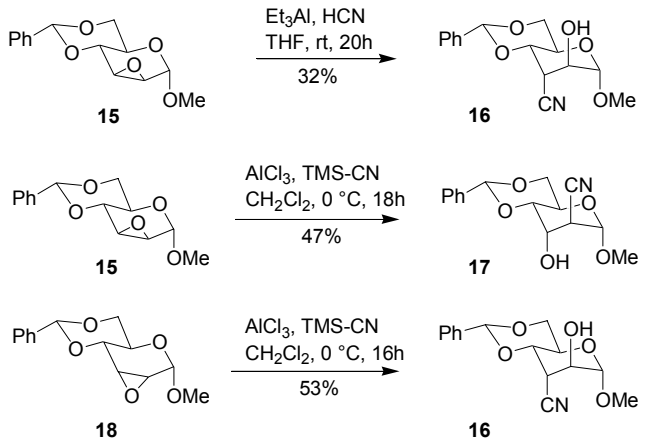


Figure 1.14: 2, 3-C Cyanodeoxy Sugars

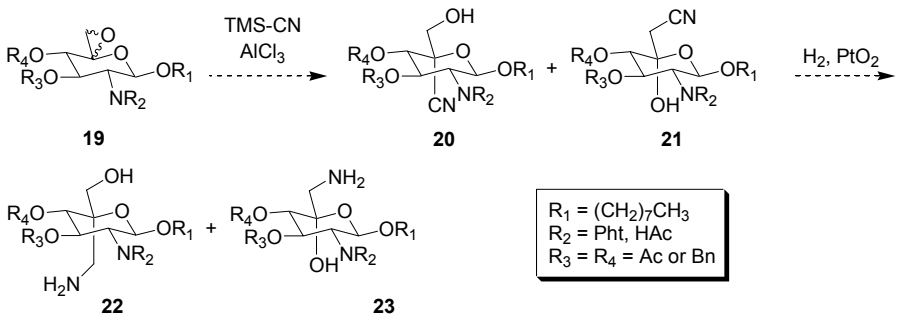


Figure 1.15: Formation of 5, 6-C Cyano Sugars

In order to evaluate the enzymes UDP-C-4-GlcNAc epimerase, GalNAcT, β-1, 4 GalT, and FucT III as described above, compounds **11**, **12** (X = F), **13a**, **13b**, **14a** and **14b** have been selected as (5-fluoro) synthetic targets for use with the epoxide fluoridolysis methodology (Figure 1.16). The (5-fluoro) glycosides could be compared to their corresponding non-fluorinated, control, substrates in order to determine the effect fluorine has on the transition state of the glycosyltransferase reaction of interest. These GalNAc and (iso)LacNAc glycosides may be accessed through the GalNAc epoxide **8** (X = H, Y = OH, Z = OH) and the (iso)LacNAc epoxides **10** as described in Figure 1.8.

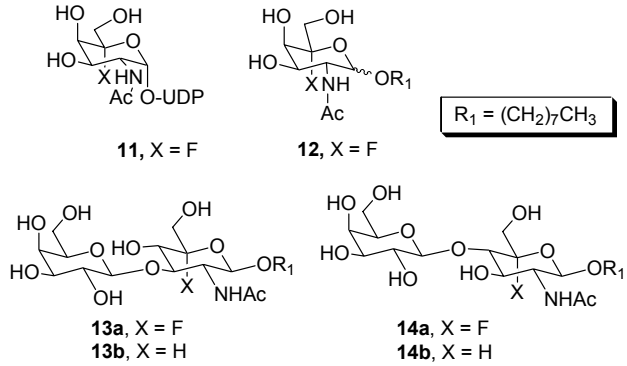


Figure 1.16: Synthetic Targets for (5-Fluoro) Carbohydrates

In addition to the GalNAc derivatives (**11** and **12**) and (iso)LacNAc glycosides (**13** and **14**), a new C-C bond formation utilizing an acid-catalyzed "C-glycosylation"

reaction will be attempted on the GlcNAc epoxide **8** (Figure 1.8, X = OH, Y = H, Z = OH). As shown in Figure 1.17, this may form a stable C-C bond at the C-5 position, **20**, allowing for greater functionalization of carbohydrates or, alternatively the regioisomer, **21**, a reducing sugar. In addition, it will be important to understand the functional group tolerance of the new cyanosilylation reaction in order to determine the scope of this methodology. As a result, both electron-withdrawing and electron-donating protecting groups will be evaluated with cyanosilylation.

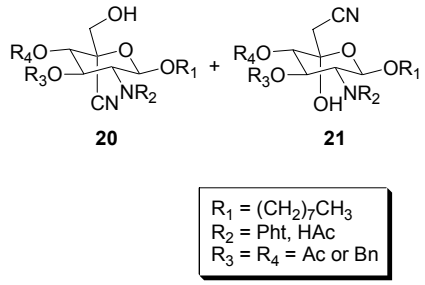


Figure 1.17: Synthetic Targets for (5-Cyano) Carbohydrates

CHAPTER 2

REVIEW OF CURRENT DISCUSSIONS OF GALACTO AND GLUCO REACTIVITIES AND CURRENT GLYCOSYLATION METHODOLOGIES

2.1 Discussion of gluco versus galacto reactivites

Glucose and galactose sugars are structurally very similar; the only difference being the position of the C-4 hydroxyl group. However, this seemingly modest distinction imparts a variety of fundamental property changes between the two sugars. It will be of interest to see how the epoxide fluoridolysis reaction may be affected by the C-4 hydroxyl position, as this has not been reported in the literature.

Studies have indicated that the electronegativity of the C-4 substituent plays a role in the rate of acetolysis of galactopyranosides (Figure 2.1).[26] The results show compound **24** acetolyzes approximately 10 times faster than **25**, which is approximately 5 times faster than **26**. In contrast, the glucopyranoside series is not as influenced by the electronegative nature of the C-4 substituent. Compound **27** is approximately 2.9 times faster than **28** and 3.3 times faster than **29**. The result of the glucopyranoside acetolysis rates is hypothesized to be due to a small "through-bond" interaction with the ring oxygen. In the case of the galacto configuration, there is a strong through-space interaction between the electronegative C-4 axial substituent and the forming oxocarbenium ion. In neutral galactopyranoside derivatives, the effect is destabilizing

due to electrostatic repulsion. During oxocarbenium ion formation, the through-space effect is stabilizing.

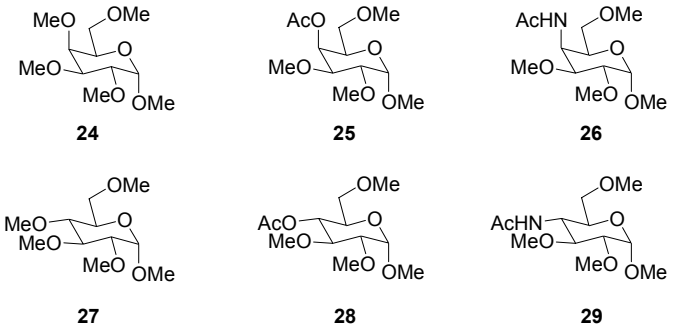


Figure 2.1: Glycopyranoside Acetolysis Substrates

2.2 Discussion of reactivity differences of carbohydrate ring positions

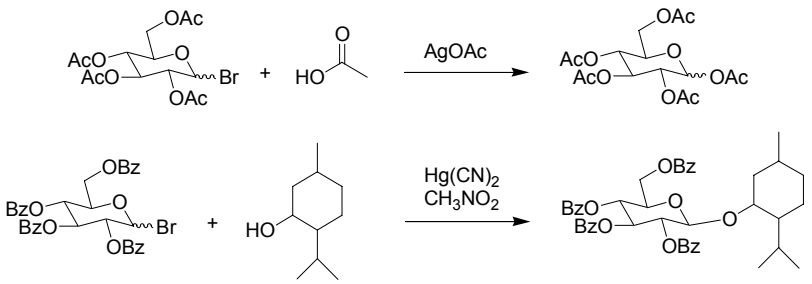
In addition to differences between gluco versus galacto configurations, each of the 6 positions of the carbohydrate ring have different reactivities. The α:β selectivity at C-1 may be influenced by the neighboring C-2 position.[27,28] In a gluco configuration, neighboring group participation on a donor substrate occurs with a participatory group at C-2 that can attack the α-face of the C-1 position. As a result, glycosylation with an acceptor preferentially forms a β-linkage. The C-3 hydroxyl is known to be a good nucleophile, but an electron-withdrawing N-phthalimido group at the C-2 position lowers the reactivity of the C-3 hydroxyl.[29] The C-4 position is known to be in general a poor nucleophile.[30] However, a C-3 and C-4 diol acceptor substrate with C-2 N-phthalimido or C-2 N-Troc will regioselectively form a 1-4 linkage.[29,31] As a result, it is important to manipulate the reactivity of each position on donor and acceptor substrates of glycosylation reactions in order to attain the desired α:β-selectivity and 1, 3 or 1, 4 regiochemistry. In order to synthesize the desired (5-fluoro) (iso)LacNAc octyl glycosides **13** and **14**, it will be necessary to perform a glycosylation reaction to form the

desired β-1, 3 and β-1, 4 disaccharides. Therefore, it will be important to design specific donors and acceptors to give the desired α:β selectivity and regiochemistry of the (iso)LacNAc derivatives. In addition to manipulating reactivities of the carbohydrate positions, the α:β-selectivity may also be influenced by the technique used to promote glycosylation.

2.3 Discussion of current glycosylation methodologies

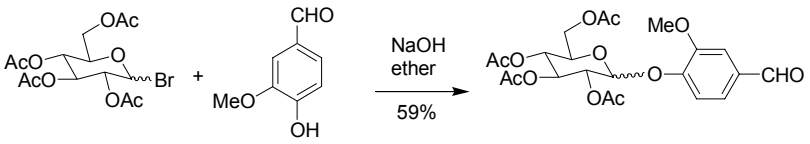
Promotion of glycosylation reactions are widely reported in the literature. The earliest glycosylation techniques include the Koenigs-Knorr, Fisher-Raske, or Helfrich methods. The Koenigs-Knorr method involves a glycosyl halide donor and either a silver or a mercury salt as a promoter (Scheme 2.1).[32,33]

Scheme 2.1



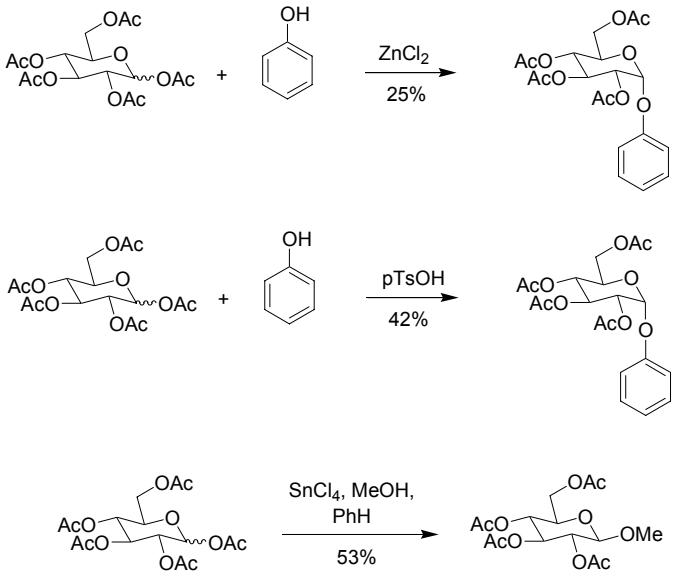
Additionally, Emil Fisher and Karl Raske developed a glycosylation reaction involving a glycosyl halide donor and an alkoxide base.[34] A caustic solution was added to the donor halide with the acceptor alcohol resulting in a mixture of α:β glycosides (Scheme 2.2).

Scheme 2.2



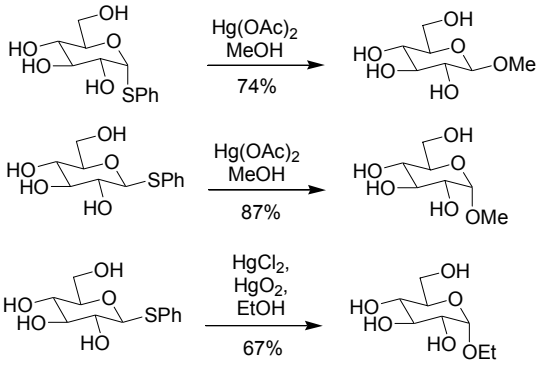
Helfrich glycosylation utilizes a Lewis acid promoter and a peracetylated glycoside donor substrate. This method forms the α- or β-glycosides in modest yields (Scheme 2.3).[35,36]

Scheme 2.3



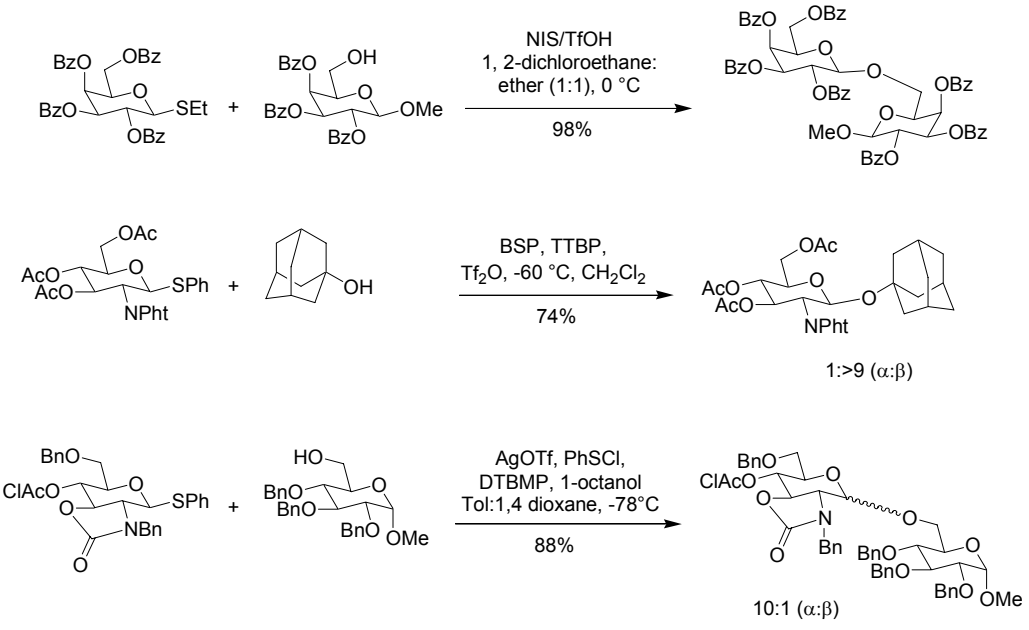
Improved α:β selectivity in glycosylation reactions are observed with phenylthioglycoside donor substrates (Scheme 2.4).[37] Thioglycoside promotion is similar to the Koenigs-Knorr promotion methods in that a mercury salt promoter used. Stereocontrol at the anomeric position for simple acceptors is readily accessible.

Scheme 2.4



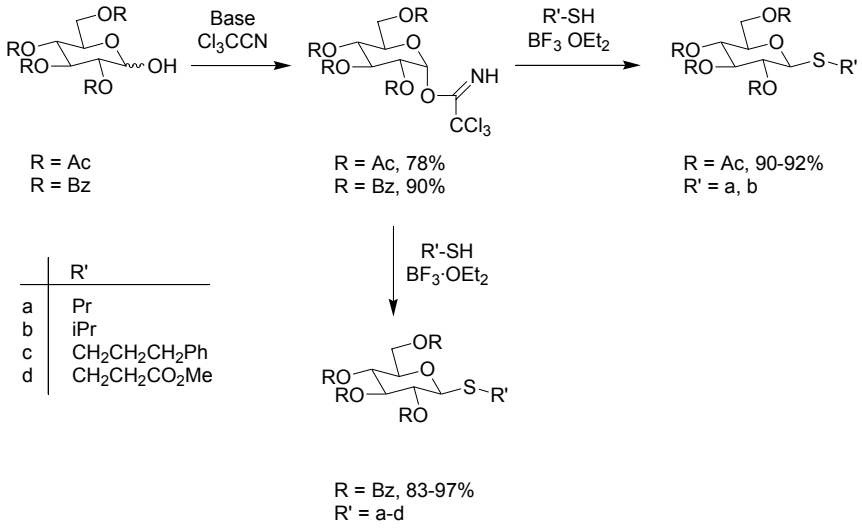
Enhanced thioglycoside activation include the promoters NIS[28], BSP[30] and PhSCl[38] (Scheme 2.5). These conditions generally proceed in good yields, allowing for good stereocontrol at C-1. A glycosyl triflate salt is formed in situ, along with formation of a disulfide leaving group upon activation from a sulfur-containing promoter. The acceptor alcohol then displaces the triflate to form the desired glycoside.[39,40]

Scheme 2.5



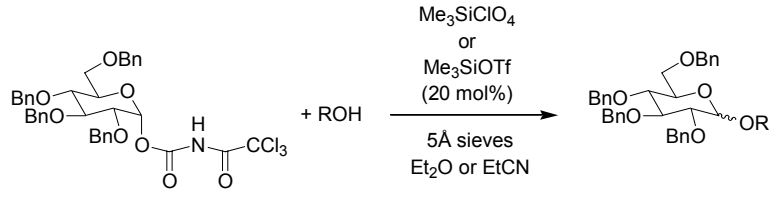
In general, good to excellent yields and stereoselectivity in glycosylation reactions may be attained using a trichloroacetimidate donor developed by Schmidt and co-workers.[41] This method uses a strong Lewis-acid promoter with improved yields compared to the previous methods described above (Scheme 2.6).[42]

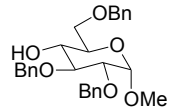
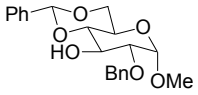
Scheme 2.6



The trichloroacetimidate methodology also allows greater flexibility of selectivity at the anomeric position. This is achieved by controlling the temperature of activation of the glycosylation reaction.[43] The use of an N-trichloroacetylcarbamate group which is analogous to a trichloroacetimidate, resulted in a dramatic difference in α:β-selectivity due to the temperature of glycosylation activation (Table 2.1). A lower temperature of activation increases β-selectivity. A higher temperature of activation predominantly yields an α-glycoside.

Table 2.1: Temperature Effects of α/β-Selectivitiy in Glycosylation Reactions



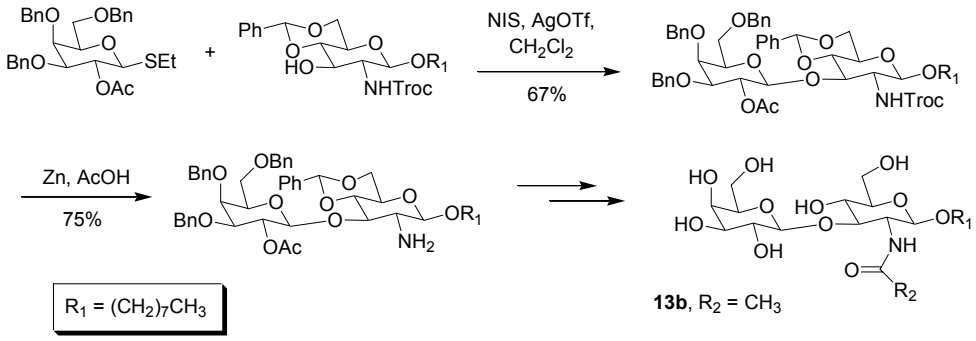
Acceptor (ROH)	α-Selective glycosylation[a]	β-Selective glycosylation[b]
	0 ºC, 5h 93%, α/β = 90/10	-40 ºC, 1.5h then -23 ºC, 16h 83%, α/β = 15/85
	0 ºC, 3h 86%, α/β = 96/4	-20 ºC, 1h 74%, α/β = 17/83

[a] Me_3SiClO_4 (20 mol %) in Et_2O

[b] Me_3SiOTf (20 mol %) in EtCN

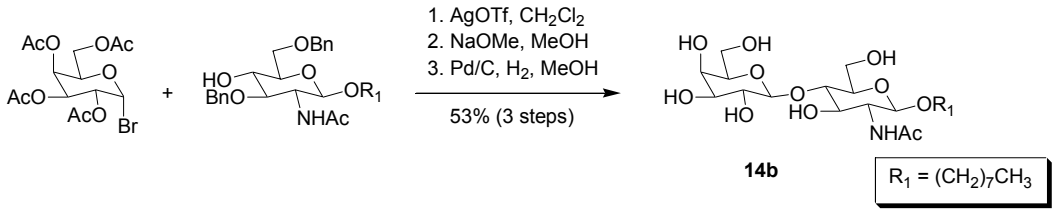
The thioglycoside method previously described has been used to synthesize compound **13b** (Scheme 2.7)[44]. The benzylidene acceptor and thioglycoside donor formed the desired disaccharide in modest yield and removal of the Troc at N-2 allowed for a library of different N-substituted β-1, 3 octyl glycosides (lacto-N-biose).

Scheme 2.7



The Koenigs-Knorr method was employed in the synthesis of the β-1, 4 octyl glycoside 14b[45] (Scheme 2.8). This procedure proceeded in good yields to form **14b**. The disadvantage of this synthesis is that the acceptor substrate is highly specific. A more divergent acceptor substrate allowing for access to multiple acceptor substrates for different regioisomers would be more useful. Chapter 4 describes syntheses for accessing both (5-fluoro) (iso)LacNAc and non-fluorinated (iso)LacNAc-octyl glycosides **13** and **14** from one readily available starting material.

Scheme 2.8



CHAPTER 3

SYNTHESIS OF C-6 PHENYLSELENIDE-GalNAc-OCTYL GLYCOSIDES AND C-6-PHENYLSELELNIDE-GalNAc-GLYCOSYL PHOSPHATES

3.1 Introduction

In order to synthesize the desired (5-fluoro) and (5-cyano) GalNAc and GlcNAc glycosides **11**, **12**, **20** and **21**, it is necessary to synthesize C-6 phenylselenide-containing glycosides (Figure 1.8). These monosaccharide selenium-containing substrates will then be transformed to their corresponding 5, 6 epoxides and subjected to either epoxide fluoridolysis or cyanosilylation. The C-6 phenylselenide-containing GalNAc glycoside synthetic targets are shown in Figure 3.1. Protecting group flexibility at C-4 is desired because of the axial –OH substituent in the galacto configuration (Figure 3.1A). It is unknown what affect the axial C-4 –OH substituent will have on fluoridolysis or cyanosilylation. Therefore, it is important to explore electron-withdrawing versus electron-donating protecting groups at C-4, as well as the potential for neighboring group participation of different protecting groups. In terms of the cyanosilylation reaction, it is unknown what the functional group tolerance of the reaction conditions will be. As a result, it will also be important to investigate the role of electron-withdrawing versus electron-donating in cyanosilylation (Figure 3.1B).

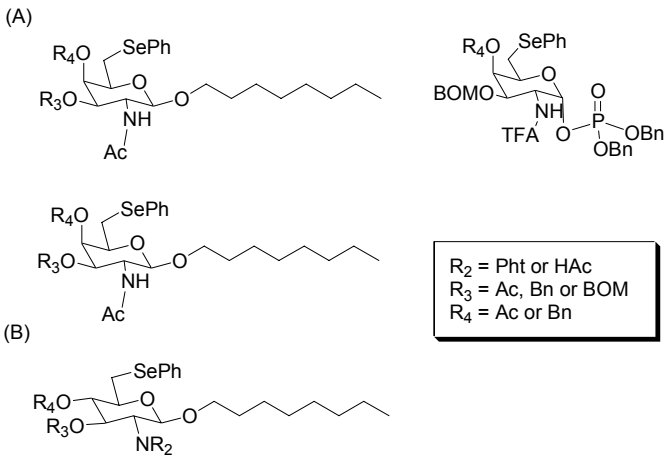


Figure 3.1:GalNAc and GlcNAc C-6 Phenylselenide Synthetic Targets

Introduction of the phenylselenide (Chapter 1, Figure 1.8) can be achieved by two different methods (Figure 3.2). One approach involves displacement of a bromide with phenylselenol (Figure 3.2A), whereas an alternative route, developed by Nicolaou and Grieco, converts a free alcohol to a phenylselenide using *N*-phenylseleno phthalimide (*N*-PSP) and PBu_3 (Figure 3.2B).[46]

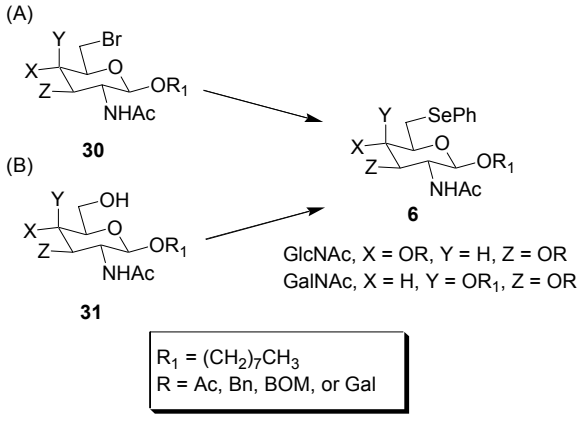


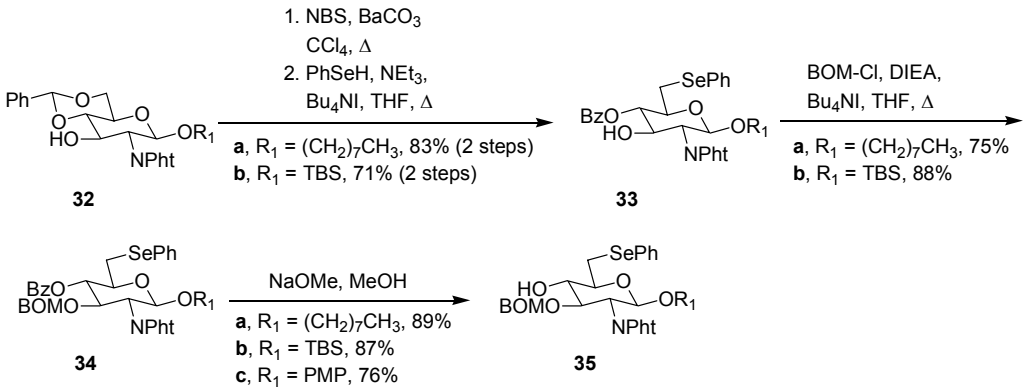
Figure 3.2: Formation of 6-SePh

Both methods have been investigated and applied in the syntheses of the glycosyl phenylselenides.

3.2 Synthesis of the β-octyl C-4–OH glycosides

In the case of the GalNAc-β-octyl glycosides, the phenylselenide has been installed via the halide displacement method (Figure 3.2A). Beginning with the known compounds **32a** and **32b**,[47] the benzylidene intermediates were opened using Hanessian-Hullar conditions[48] that produced a C-6 bromide and resulted in selective protection of the C-4 position as a benzoyl ester (Scheme 3.1). A non-amide group, e.g. phthaloyl, at the C-2 nitrogen is necessary for Hanessian-Hullar conditions, which proceeds through radical abstraction of the benzylidene hydrogen by $Br^{\cdot}$ during the reaction. Instead of abstracting the benzylic hydrogen, the radical could abstract the amide hydrogen on the nitrogen, resulting in undesired reaction(s) and/or decomposition. The bromide was then displaced using PhSeH, NEt_3 and Bu_4NI (as a phase-transfer catalyst) to form the phenylselenides, **33a** and **33b**. The addition of Bu_4NI dramatically decreased the reaction time from 5 days to overnight. The free C-3 –OH groups were protected with a benzyloxymethyl (BOM) ether group to form **34a** and **34b**. Compound **34c** was synthesized as reported by Matt Hartman.[8] The order of the reaction sequence is important to avoid formation of an undesired C-6 chloro by-product (Scheme 3.2). The C-6 bromide must be displaced first by PhSeH before the C-3 protection, otherwise the release of chloride from the BOM-Cl reagent will displace the bromide and result in a 3:1 mixture of C-6 Br and C-6 Cl glycoside (Table 3.1). Attempts at sequestering the released chloride with silver salts proved unsuccessful. The resulting differentially protected glycosides **34a, 34b** and **34c** were transformed to **35a, 35b,** and **35c** by removal of the C-4 benzoyl protecting group with NaOMe.

Scheme 3.1



Scheme 3.2

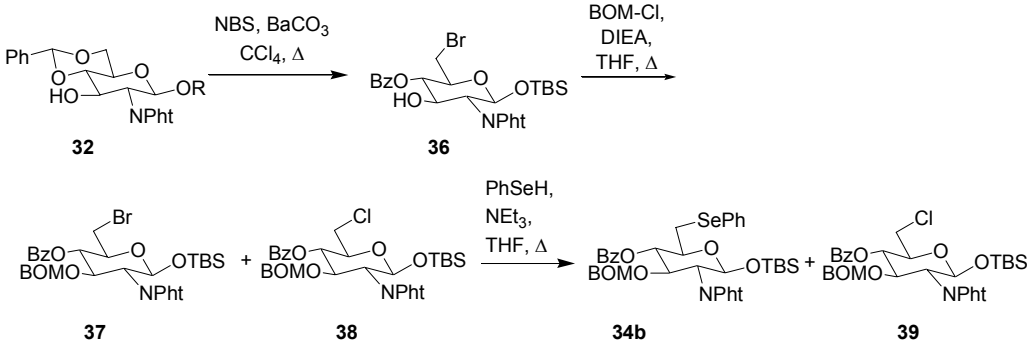


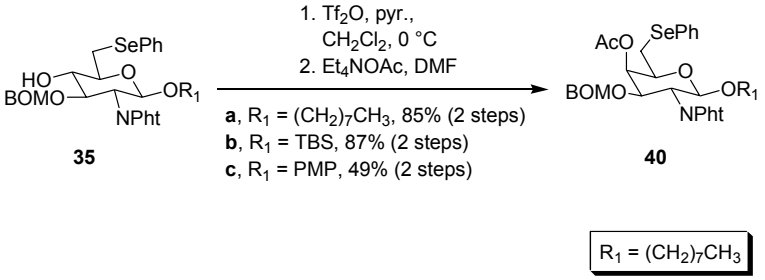
Table 3.1: Attempts at Sequestering Released Chloride During C-3 BOM Protection

BOM-Cl	DIEA	Silver Salt	Result
5 (eq.)	5.5 (eq.)	None	**34b**/**39** (3:1)
2 (eq.)	2.5 (eq.)	None	**34b**/**39** (15:1)
5 (eq.)	5.5 (eq.)	$AgCO_3$	Decomposed
3 (eq.)	3.5 (eq.)	Ag_2O	Decomposed

3.3 Inversion of configuration from gluco to galacto

The inversion of configuration was accomplished via triflate formation and the S_N2 displacement of the triflate by Et_4NOAc (Scheme 3.3).[49] Synthesis of **40c** was performed once and not optimized, but **40a** and **40b** proceeded in good yields to form the desired GalNAc glycosides.

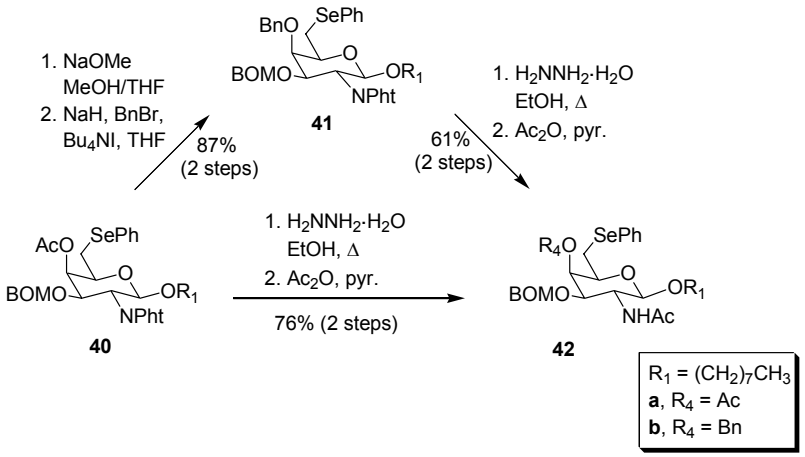
Scheme 3.3



3.4 Synthesis of 6-SePh-GalNAc-β-octyl glycoside

Protecting group flexibility at the C-4 position was desired since this position would be adjacent to the 5, 6 epoxides (as described in 3.1). The role of an electron-withdrawing versus electron-donating protecting groups is of interest at C-4 as it is unknown how it will affect fluoridolysis and cyanosilylation. For the C-4 acetate (electron-withdrawing) derivative, the phthaloyl and acetyl groups of **40a** were removed and the resulting 2-amino, 4-hydroxy glycoside was N- and O-acetylated to give **42a** (Scheme 3.4). Alternatively, the C-4 acetate was removed by NaOMe and protected as a benzyl ether (electron-donating protecting group) using the method developed by Karst and coworkers.[50] The phthaloyl group was then removed and acetylated to form **42b**.

Scheme 3.4



3.5 Synthesis of 6-SePh-GalNAc-α-octyl glycoside

Installing the phenylselenide on the GalNAc-α-octyl glycoside was investigated using both the halide displacement and the *N*-PSP methods. First, the α-linkage needed to be in place and several methods were investigated.

Initially, a thioglycoside was used because of the reported high α-selectivity in the literature (Scheme 3.5). Beginning with the glycoside **43**, the phenylthio glycoside was formed using $BF_3{\cdot}OEt_2$ and PhSH to form **44**.[51] The benzylidene **45** was then formed based on the procedure of Miyajima and coworkers[52] by removing the acetyl protecting groups to form the triol and then using $PhCH(OMe)_2$ and pTsOH. After formation of the oxazolidinone, **46**[38], glycosylation to form the α-linkage was attempted using AgOTf, PhSCl, DTBMP and 1-octanol.[38] However, in contrast to the literature reports, the reaction failed to produce the desired α-octyl glycoside and starting materials were recovered (Table 3.2, entry 1). Other methods of thioglycoside activation were attempted,

but also failed to produce the desired α-linkage (Table 3.2, entries 2-4).[38-40] Starting materials were recovered in each of the methods described in Table 3.2.

Scheme 3.5

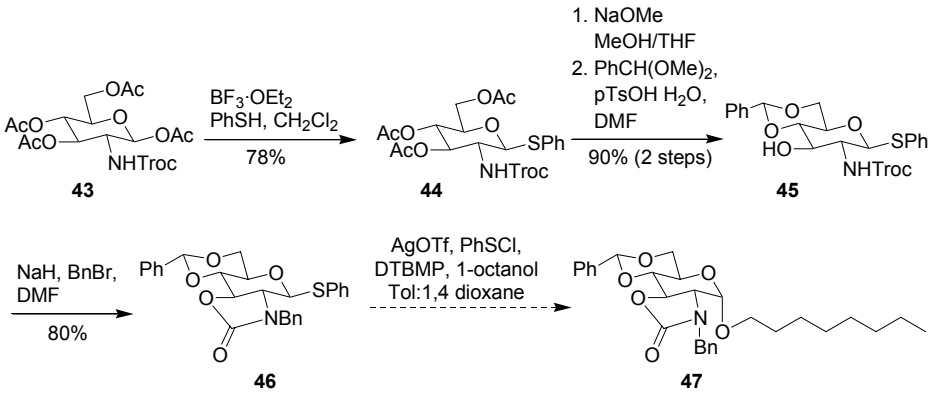


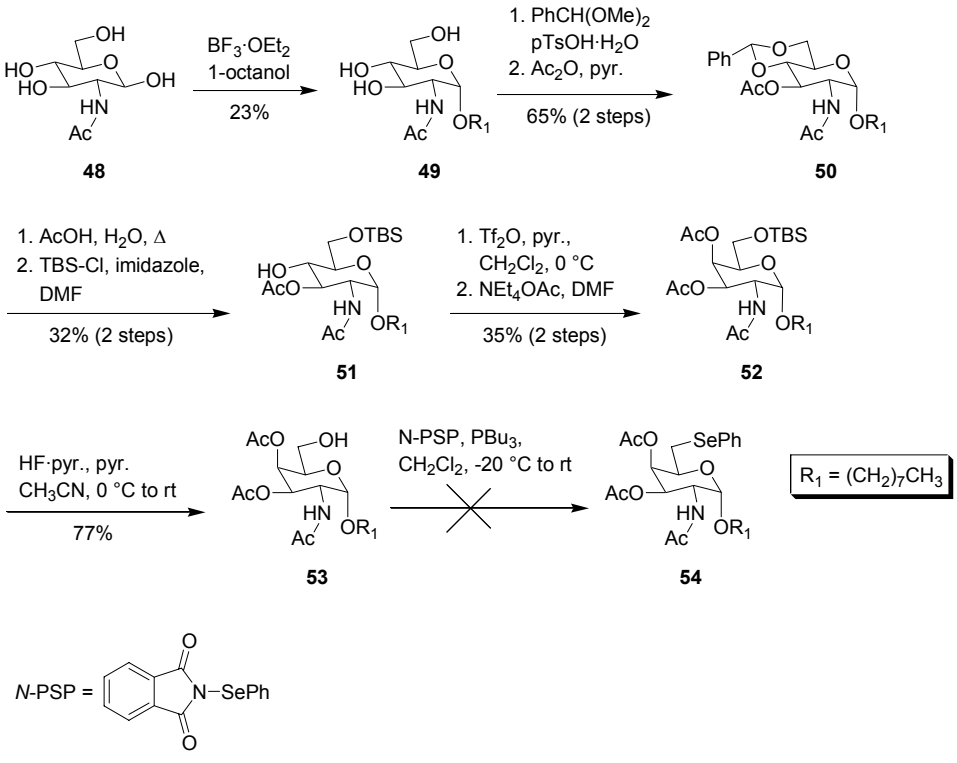
Table 3.2: Attempts at Formation of the α-Octyl Glycoside

Entry	Conditions	Result
1	AgOTf, PhSCl, DTBMP, 1-octanol Tol:1,4 dioxane, -78°C	No Product Formed
2	AgOTf, PhSCl, TTBMP, 1-octanol Tol:1,4 dioxane, -78°C	No Product Formed
3	BSP, DTBMP, Tf_2O, 1-octanol CH_2Cl_2, -60 °C	No Product Formed
4	NIS, DTBMP, TMSOTf, 1-octanol CH_2Cl_2, rt	No Product Formed

An alternative to thioglycoside activation involved installing the octyl side chain at the beginning of the synthesis by Lewis acid activation of *N*-acetyl-D-glucosamine, **48**,

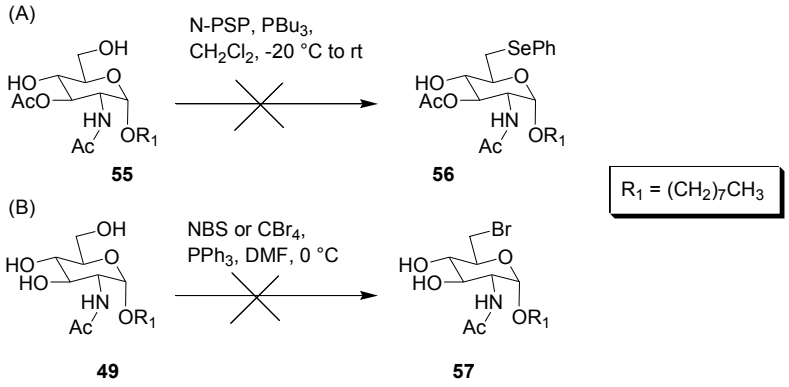
in neat 1-octanol (Scheme 3.6).[29,53] The α-glycoside **49**, was then converted to the benzylidene and the free C-3 alcohol acetylated to yield compound **50**. The 4, 6-benzylidene of compound **50** was opened with acid catalysis to give the diol and the C-6 position was selectively protected as a TBS ether to form **51**. The gluco configuration was converted to the galacto configuration via triflate formation at the C-4 position and displacement of the triflate by Et_4NOAc. The TBS silyl ether was then removed to give the free C-6 alcohol, **53**. However, attempts at formation of the phenylselenide with the *N*-PSP method did not form the desired phenylselenide glycoside, **54**. Perhaps the reaction failed due to neighboring group participation from the axial C-4 acetate group next to the C-6 alcohol. Compound **54** was recovered with no decomposition detected.

Scheme 3.6



In addition to **53**, diol **50** was also subjected to the same *N*-PSP conditions (Scheme 3.7). However, only starting material was recovered. Alternatively, formation of a C-6 Br, **57**, was attempted using NBS or CBr_4 with PPh_3.[54] Compound **49** was recovered and the desired bromide, **57**, was not observed (Scheme 3.7). The α-linkage was not pursued further.

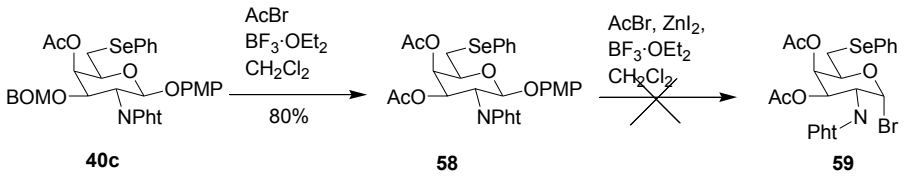
Scheme 3.7



3.6 Synthesis of 6-SePh-GalNAc phosphate

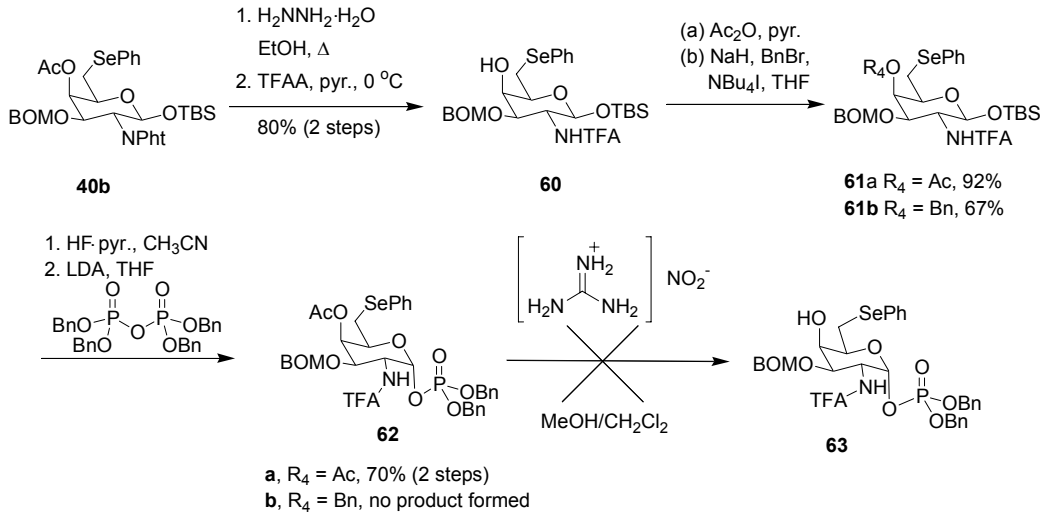
In pursuit of the 6-SePh-GalNac phosphate glycosides, the BOM group at C-3 of **40c**, was removed with $BF_3{\cdot}OEt_2$ and the resulting hydroxyl group selectively acetylated with AcBr in a one-pot procedure to afford **58** (Scheme 3.8). However, attempts at deprotection of the PMP group failed with AcBr, ZnI_2 and $BF_3{\cdot}OEt_2$. Following literature procedures, PMP deprotection and conversion to the glycosyl bromide was successful in a model reaction.[55] However, compound **58** could not be converted to **59** under identical conditions.

Scheme 3.8



Consequently, the TBS ether was used because of its ease of deprotection (Scheme 3.9). The phthaloyl and acetyl protecting groups on compound **40b** were removed via hydrazinolysis. The free C-2 amine was N-trifluoroacetylated with trifluoroacetic anhydride (TFAA) and pyridine forming the C-2 trifluoroacetamide as well as the TFA ester at C-4. The C-4 TFA ester was removed with a sodium bicarbonate wash to give the free C-4 –OH, **60**. The resulting C-4 –OH group was protected with acetic anhydride and pyridine to yield **61a**. Alternatively, the C-4 –OH group was protected as a benzyl ether to give **61b**. The TBS silyl ether was removed to form the reducing sugar, which was then phosphorylated with tetrabenzyl pyrophosphate (TBPP) to give compound **62a**. The C-2 trifluoroacetamide is critical for the stability of the glycosyl phosphate at C-1.[56] The electron-withdrawing effects of fluorine stabilize the phosphate, allowing it to be purified by flash column chromatography and withstand multiple synthetic organic reaction conditions.[8] When an acetamido group is at C-2, the glycosyl phosphate is unstable and cannot be purified via flash column chromatography.[57] The same sequence of phosphorylation conditions used to form **62a** was unsuccessful in forming **62b**. Since flexibility was again desired at the C-4 position, attempts at removal of the acetate protecting group to form **63** failed using the mild conditions of guanidine/guanidinium nitrate[58].

Scheme 3.9



It is proposed that the failed phosphorylation with O-Bn at C-4 is due to the fact that the O-Bn group cannot participate in the reaction at C-1 of the reducing sugar. A C-4 acetate in a galactose derivative can participate across the ring[59] and possibly is coordinating with the Li^+ ion generated from the LDA deprotonation (Figure 3.3, A). The coordination helps pull the Li^+ ion away from the oxyanion at C-1, allowing for nucleophilic attack of the TTBP. The C-4 Bn ether cannot coordinate to the Li^+ ion and the oxyanion is not as exposed and is unable attack the TTBP (Figure 3.3, B). A better leaving group on the phosphorylating agent, such as a phosphoramidite, may be needed to form the desired C-4 Bn glycosyl phosphate.

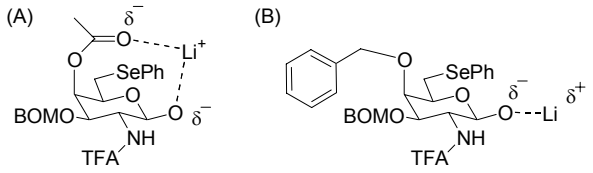
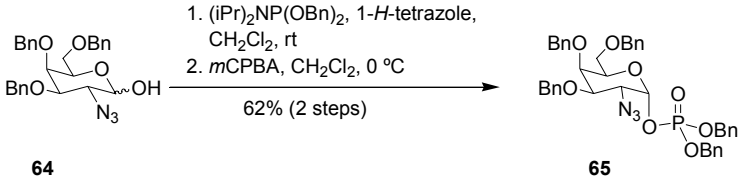


Figure 3.3: C-4 Ac vs. C-4 Bn Phosphorylation

As a result of the failure to obtain **62b** as described above, a new method was attempted following the work of Thiem and Lazarevic (Scheme 3.10)[60], in which the reducing sugar **64** was converted to a phosphite using dibenzyl-*N*, *N*'-diisopropylphosphoramidite $(iPr)_2NP(OBn)_2$ and 1-*H*-tetrazole and then oxidized with *m*CPBA to form the phosphate **65** in a one-pot procedure.

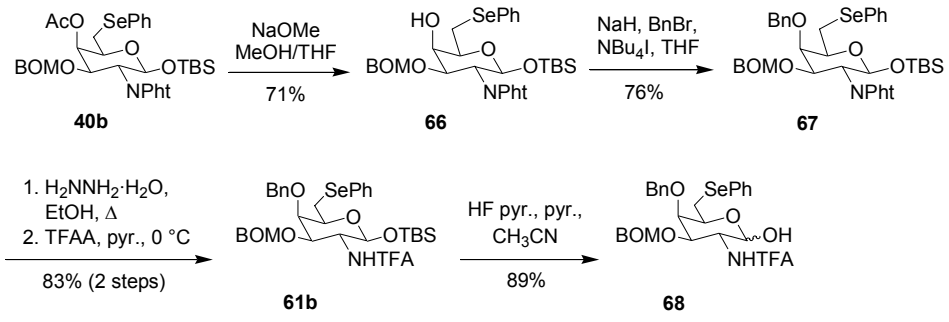
Scheme 3.10



64 **65**

The C-4 Bn ether protection described in Scheme 3.9 was optimized and a new route was developed and is shown in Scheme 3.11. The C-4 acetate was removed with NaOMe and the resulting free alcohol protected with a benzyl ether to give **67**. The phthaloyl group was removed and trifluoroacetylated to give **61b**, in a higher yielding sequence than previously described in Scheme 3.9. The TBS silyl ether was then removed to form the reducing sugar **68**.

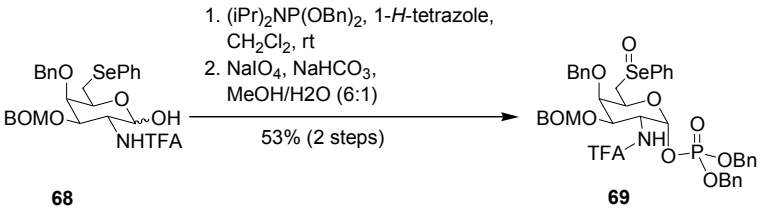
Scheme 3.11



40b **66** **67** **61b** **68**

Following the Thiem procedure, phosphorylation of **68** was achieved by formation of the phosphite followed by subsequent oxidation of the phosphite to the phosphate (Scheme 3.12). The oxidation conditions ($NaIO_4$ and $NaHCO_3$) resulted in the oxidation of both the phenylselenide and phosphite moeities to give the glycosyl phosphate **69**.

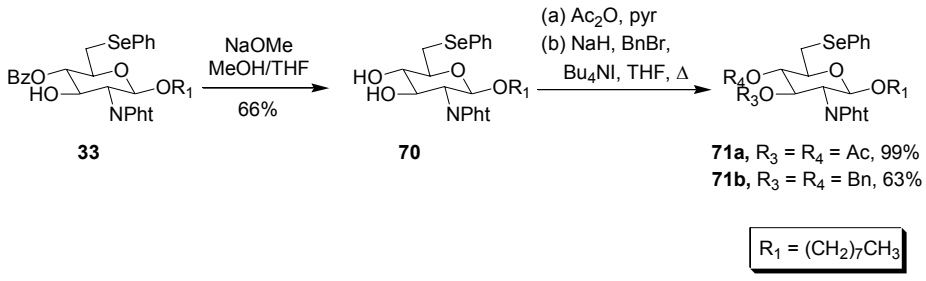
Scheme 3.12



3.7 Synthesis of cyanosilylation precursor phenylselenides

Acid-catalyzed glycosylation of 2, 3 epoxides has been achieved using a strong Lewis acid with TMS-CN as described in Chapter 1, Figure 1.14. In order to test acid-catalyzed glycosylation on 5, 6 epoxides, the phenylselenides **71a** and **71b** were synthesized (Scheme 3.13). These precursors were designed to incorporate electron-withdrawing and electron-donating protecting groups in order to explore functional group tolerance of cyanosilylation.

Scheme 3.13



3.8 Conclusions

Formation of the C-6 selenium-containing GalNAc-β-octyl glycosides **42a** and **42b** with either electron-withdrawing (**42a**) or electron-donating (**42b**) protecting groups at C-4 proceeded in good yields. However, installation of the C-6 phenylselenide α-glycoside was unsuccessful with either thioglycoside activation (Table 3.2), N-PSP conversion of a C-6 OH to the C-6 SePh (Scheme 3.6), or formation of a C-6 Br (Scheme 3.7). In pursuit of the glycosyl phosphate, the electron-withdrawing C-4 acetate GalNAc α-phosphate **63** was formed in good yields from **62a** in a 2-step process of deprotonation of the C-1 –OH with LDA and phosphorylation with TBPP. In contrast, attempts at phosphorylation of the C-4 Bn ether reducing sugar **68** with TBPP were not successful in forming the desired α-phosphate. Phosphitylation of **68** was successful using $(iPr)_2NP(OBn)_2$, followed by oxidation of the phosphite to the phosphate. Synthesis of the GlcNAc phenylselenides **71a** and **71b** was formed in good yields with both electron-withdrawing and electron-donating protecting groups at C-3 and C-4.

With the C-6 phenylselenide-containing GalNAc and GlcNAc glycosides (**42a**, **42b**, **71a** and **71b**) and glycosyl phosphates (**63** and **69**) in hand, the phenylselenides will be transformed into their corresponding 5, 6 epoxides by a two-step process of oxidation of the selenide to the selenoxide and thermal elimination to an olefin (Chapter 5). Epoxidation of the resulting olefin with DMDO (Figure 1.8) should yield the desired GalNAc and GlcNAc epoxides **8**. Epoxide fluoridolysis and cyanosilylation will be attempted on the epoxides to form the target compounds **11**, **12**, **20** and **21**.

CHAPTER 4

SYNTHESIS OF C-6-PHENYLSELENIDE LacNAc DISACCHARIDES AND (iso)LacNAc DISACCHARIDES

4.1 Introduction

In order to evaluate the (5-fluoro) (iso)LacNAc glycosides (**13a** and **14a**) as mechanistic probes of FucT III-catalyzed glycosylation described in Chapter 1, it is necessary to synthesize the C-6 phenylselenide-containing β-1, 3 and β-1, 4 octyl glycosides (Figure 4.1). Formation of these target compounds proves synthetically challenging as glycosylation has not been reported using selenium-containing glycosides. Once installed, the phenylselenide glycosides may be transformed to the desired epoxides **10**, which can undergo epoxide fluoridolysis to form the desired (5-fluoro) glycosides **13a** and **14a**.

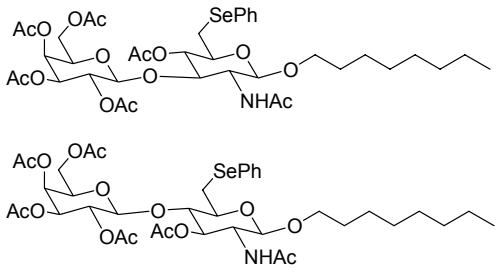


Figure 4.1: isoLacNAc and LacNAc C-6 Phenylselenide Synthetic Targets

In addition to an octyl glycoside, an 8-methoxycarbonyloctyl (8-Mco) group could also be used at the C-1 position. The advantages of 8-Mco are the increase glycoside solubility when exposed to enzymatic buffer conditions. The disadvantages of 8-Mco are it cannot withstand several reaction conditions and 8-methoxycarbonyl octanol is costly. The octyl side chain is a known substrate for glycosyl transferase enzymes and can withstand broad synthetic reaction conditions. An octyl glycoside is necessary for the Sep-Pak assay used to evaluate the enzyme as described in Chapter 1.

There are two possibilities for forming the C-6 selenium-containing disaccharides with either an 8-Mco or octyl glycoside (Figure 4.2). Either phenylselenide monosaccharide acceptors (**33** or **35**), discussed in Chapter 3, are coupled with a galactosyl donor, or the phenylselenide is introduced after formation of the desired disaccharide linkage using the non-seleno precursors (**32** or **72**).

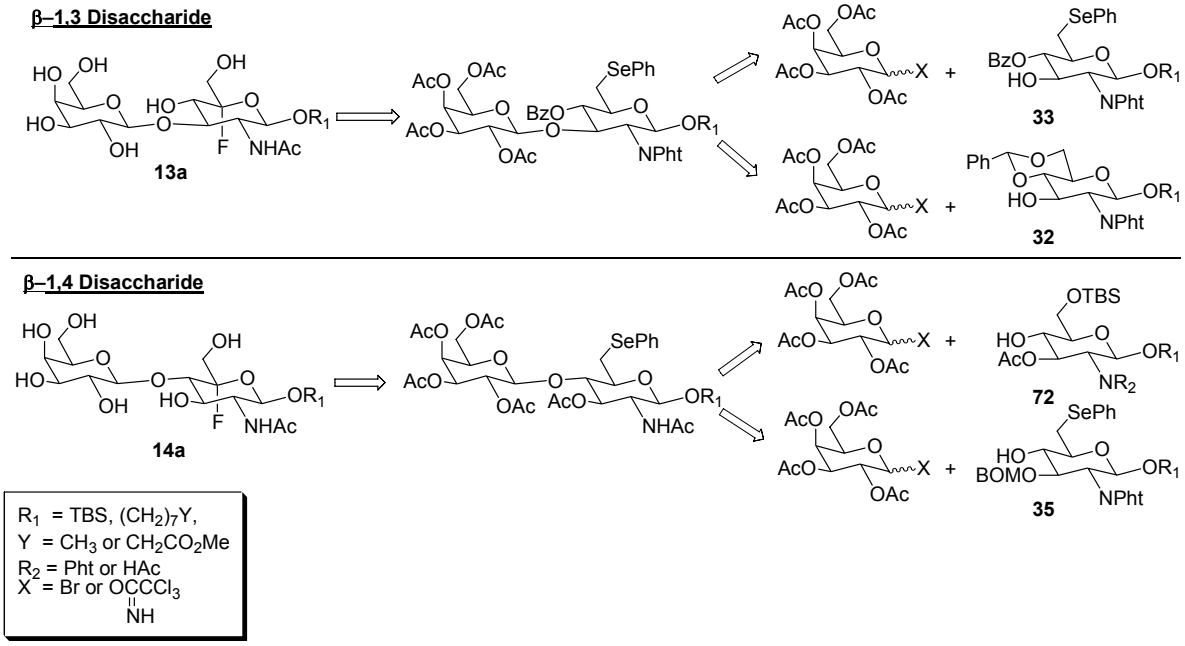
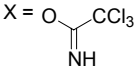


Figure 4.2: Retrosynthetic Analysis for C-6 Phenylselenide Glycosides as Precursors of 5-(Fluoro) (iso)LacNAc Glycosides

4.2 Attempts at the synthesis of 6-SePh-(iso)LacNAc-β-octyl glycoside with selenium-containing acceptor substrates

The phenylselenide monosaccharide acceptors **73**[1] and **33b** were evaluated first as they were readily available (Table 4.1). Using Koenigs-Knorr and trichloroacetimidate glycosylation reactions discussed in Chapter 2, no disaccharide formation was observed. Compounds **73** and **33b** were recovered, along with the hydrolysis products derived from the donors **74** and **75**.

Table 4.1: β-1, 3 Glycosylation Attempts with Phenylselenide Monosaccharide Acceptor Substrates

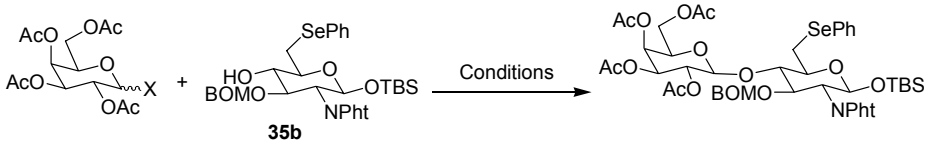
Entry	Donor	Acceptor	Conditions	Results
1	X = Br **(74)**	$R_1 = (CH_2)_8CO_2Me$ **(73)**	$Hg(CN)_2$ $CaSO_4$, 40 °C CH_2Cl_2/CH_3NO_2	No Product Formed
2	X = Br **(74)**	R_1 = TBS **(33b)**	$Hg(CN)_2$ 3Å sieves, 40 °C CH_2Cl_2/CH_3NO_2	No Product Formed
3	X =  **(75)**	R_1 = TBS **(33b)**	TMS-OTf 3Å sieves, CH_2Cl_2, 0°C	No Product Formed

Following the β-1, 3 glycosylation reactions previously attempted in Table 4.1, the phenylselenide-containing monosaccharide acceptor substrate **35b** was used to attempt formation of the desired β-1, 4 disaccharides (Table 4.2). The results were

[1] Compound **73** was isolated as a by-product of a reaction previously performed in our lab by Esther Joo.

identical to the isoLacNAc results and are shown in Table 4.1. The phenylselenide monosaccharide acceptors as well as the donor hydrolysis product were fully recovered.

Table 4.2: β-1, 4 Glycosylation Attempts with Phenylselenide Containing Monosaccharide Acceptor Substrates



Entry	Donor	Conditions	Results
1	X = Br **(74)**	AgOTf, 3Å sieves CH_2Cl_2, 0°C to rt	No Product Formed
2	X = Br **(74)**	AgOTf, TMU, 3Å sieves CH_2Cl_2, 0°C to rt	No Product Formed
3	X = Br **(74)**	$Hg(CN)_2$ $CaSO_4$, 40 °C CH_2Cl_2/CH_3NO_2	No Product Formed
4	X = O, CCl_3, NH **(75)**	TMS-OTf, 3Å sieves, CH_2Cl_2, 0 °C	No Product Formed

A proposed hypothesis as to why the phenylselenide monosaccharide acceptors are unable to form the desired disaccharide linkages is shown in Figure 4.3. It is presumed that the nucleophilic nature of C-6 selenium is greater than that of the C-3 or C-4 –OH acceptors and consumes the donor substrates in a non-productive manner.

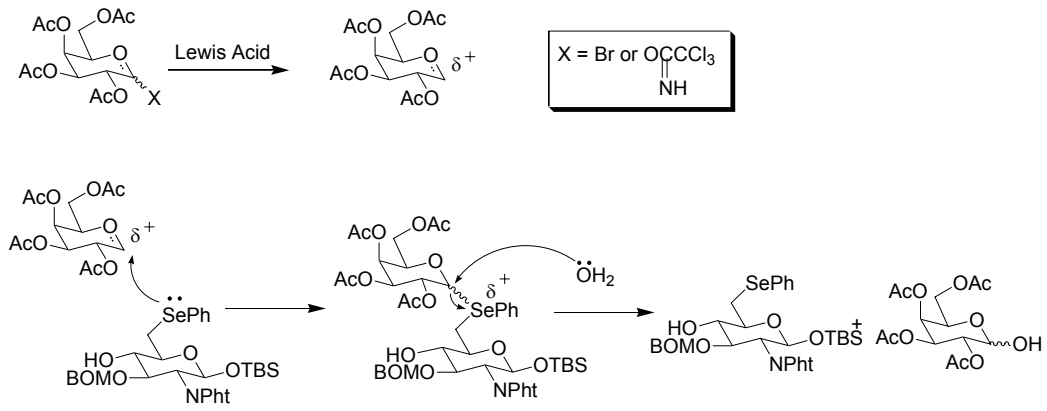
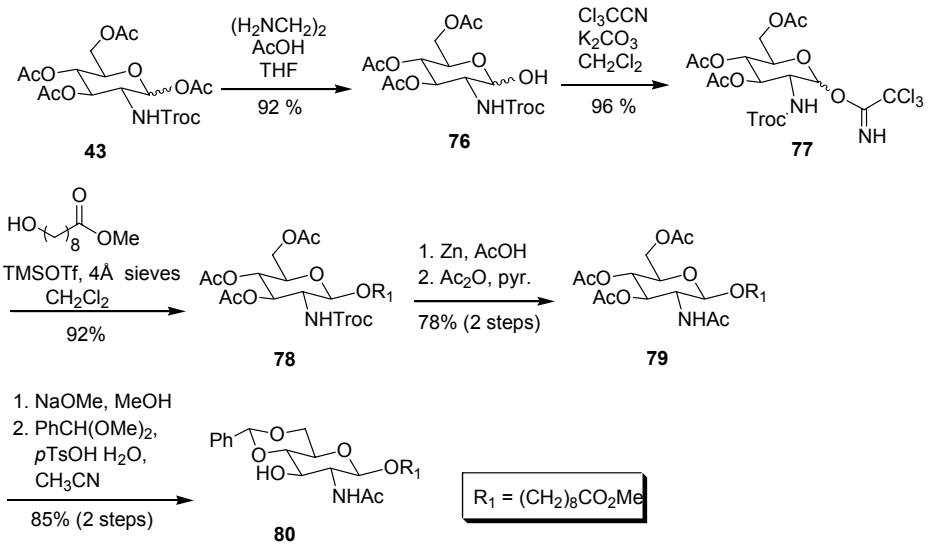


Figure 4.3: Hypothesis for Non-productive Phenylselenide Monosaccharide Acceptors Disaccharide Formation

4.3 Synthesis of 6-SePh-(iso)LacNAc-β-octyl glycoside with non-selenium-containing acceptor substrates

Given that the C-6 phenylselenide monosaccharide acceptors were unable to form the desired disaccharides, attention was turned toward the non-seleno-containing acceptors. The synthesis of the β-1, 3 glycoside with an 8-Mco side chain at C-1 was investigated. This approach utilized a trichloroacetimidate donor substrate, **77**.[61] In order to direct glycosylation towards the β configuration, a Troc group was used at C-2, due to its high β selectivity[62]. After installation of the β-8-Mco side chain at C-1, the Troc group was then removed to form the free amine and N-acetylated to give **79**. The benzylidene **80** was formed using benzaldehyde dimethyl acetal ($PhCH(OMe)_2$) and tosic acid monohydrate ($pTsOH \cdot H_2O$) from a modified Schmidt[63] procedure.

Scheme 4.1

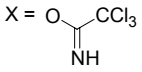
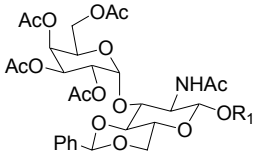
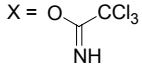


The Koenigs-Knorr and trichloroacetimidate methodologies (as described in Chapter 2) were applied in the formation of the desired β-1, 3 linkage. The Koenigs-Knorr method utilized either $Hg(CN)_2$[64] or AgOTf[65] as an activator with a glycosyl bromide donor (

Table 4.3). The best Koenigs-Knorr activator proved to be $Hg(CN)_2$. However the reaction required two days with mild heating. The trichloroacetimidate donor **75** and TMS-OTf activator (

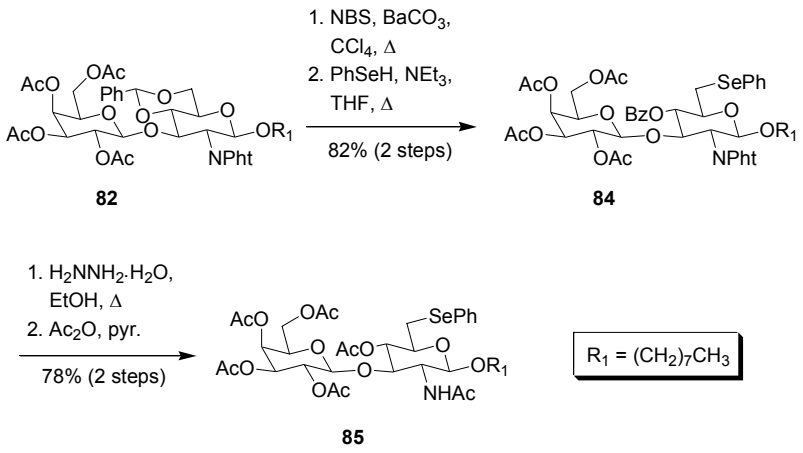
Table 4.3, entries 4 and 5) produced the desired β-1, 3 disaccharides in the highest yields and lowest reaction times. These reactions were temperature sensitive, with a lower activation temperature yielding the desired β-linkage[66] (**82**) versus a warmer temperature, which gives the α-linkage (**83**).[43]

Table 4.3: β-1, 3 Glycosylation Attempts with Non-selenium Containing Monosaccharide Acceptor Substrates

Entry	Donor	Acceptor	Conditions	Disaccharide	Yield
1	X = Br **(74)**	$R_1 = (CH_2)_8CO_2Me$ R_2 = NHAc **(80)**	AgOTf, 3Å sieves, CH_2Cl_2, 0°C to rt	$R_1 = (CH_2)_8CO_2Me$ R_2 = NHAc **(81)**	45%
2	X = Br **(74)**	$R_1 = (CH_2)_8CO_2Me$ R_2 = NHAc **(80)**	$Hg(CN)_2$, $CaSO_4$, 40 °C CH_2Cl_2/CH_3NO_2	$R_1 = (CH_2)_8CO_2Me$ R_2 = NHAc **(81)**	75%
3	X = Br **(74)**	$R_1 = (CH_2)_7CH_3$ R_2 = NPht **(32)**	$Hg(CN)_2$, $CaSO_4$, 40 °C CH_2Cl_2/CH_3NO_2	$R_1 = (CH_2)_7CH_3$ R_2 = NPht **(82)**	30%
4	X =  **(75**	$R_1 = (CH_2)_8CO_2Me$ R_2 = NHAc **(80)**	TMS-OTf, 3Å sieves, CH_2Cl_2, 0 °C	 $R_1 = (CH_2)_8CO_2Me$ R_2 = NHAc **(83)**	81 %
5	X =  **(75)**	$R_1 = (CH_2)_7CH_3$ R_2 = NPht **(32)**	TMS-OTf, 3Å sieves, CH_2Cl_2, -20 °C to rt	$R_1 = (CH_2)_7CH_3$ R_2 = NPht **(82)**	83%

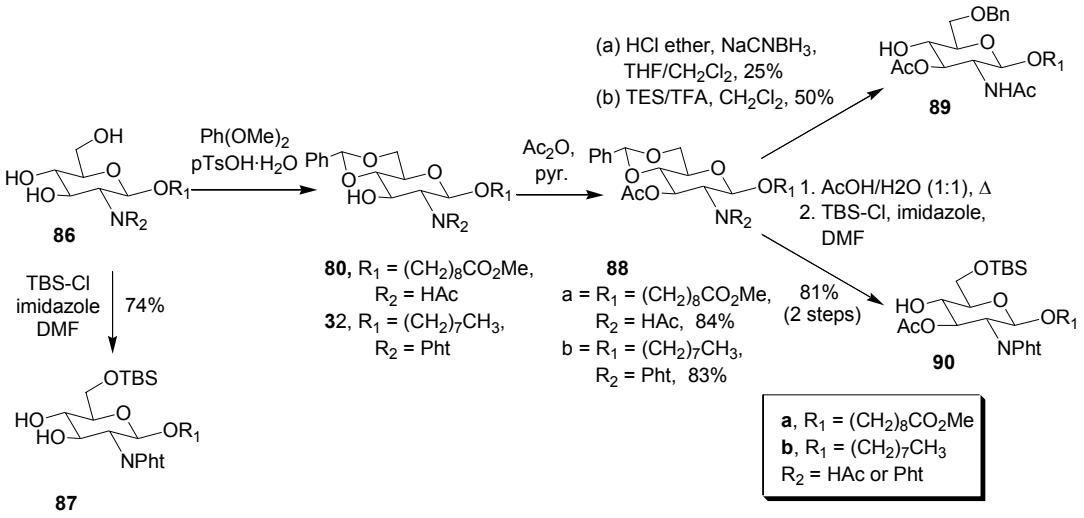
The non-selenium containing disaccharide **82** was converted to the C-6 phenylselenide with Hannessian-Hullar conditions and displacement of the C-6 bromide with PhSeH and NEt_3 to give **84** (Scheme 4.2). The addition of Bu_4NI resulted in a significant formation of a C-6 methyl by-product, and was avoided during bromide displacement. The N-phthaloyl, O-benzoyl and O-acetyl protecting groups were removed by $H_2NNH_2 \cdot H_2O$ and a global N- and O-acetylation were performed to yield the desired C-6 phenylselenide-containing disaccharide glycoside **85**.

Scheme 4.2



The β-1, 4 non-seleno acceptor substrates were synthesized using the precursors, **32** and **80**, employed in the synthesis of β-1, 3 acceptor substrates. In order to manipulate the C-6 position and introduce a phenylselenide after disaccharide formation, a strategy was developed to isolate the C-6 –OH (Scheme 4.3). Either a reduction of the benzylidene **80** to a C-6 benzyl ether or acid-catalyzed opening of the benzylidene **32**[67] followed by selective protection with a TBS[68] group would differently protect the C-6 position. Reduction of the benzylidene using either HCl in ether with $NaCNBH_3$,[69] or TES and TFA[70,71] to form the C-6 Bn ether, **89**, proved unreliable and low yielding. Opening of the benzylidene with $AcOH/H_2O$ and selective protection of the free C-6 alcohol as a TBS ether to give, **87** or **90**, proved to be better yielding and more reliable than the benzylidene reduction.

Scheme 4.3



In comparison to the β-1, 3 reactions (

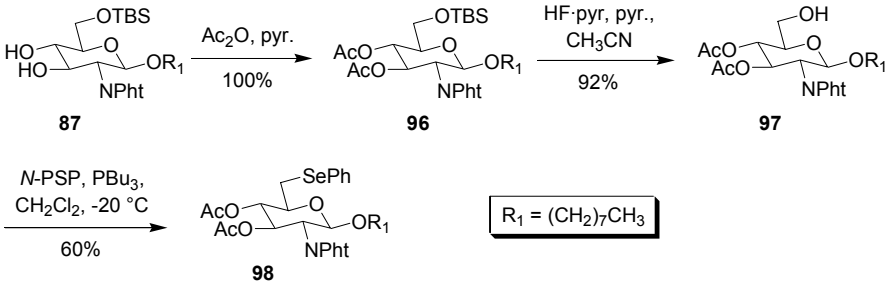
Table 4.3), similar results were observed with the non-selenium containing monosaccharide acceptors for the β-1, 4 glycosylation conditions (Table 4.4). The Koenigs-Knorr method produced the desired β-linked disaccharide but in poor yields, even with the addition of 1, 1, 3, 3-tetramethylurea (TMU)[72] (Table 4.4, entry 1). The trichloroacetimidate method was again superior to the Koenigs-Knorr method in terms of yields and reaction time. In the case of Table 4.4 entry 4, the TBS glycoside was removed with $BF_3 \cdot OEt_2$ with an extended reaction time of 1 ½ hours. In the case of Table 4.4 entries 2 and 5, the acceptors **91** and **87** and TMS-OTf promoter successfully retained the TBS ether at C-6 to give compounds **93** and **95**.[73]

Table 4.4: β-1, 4 Glycosylation Attempts with Non-selenium Containing Monosaccharide Acceptor Substrates

Entry	Donor	Acceptor	Conditions	Disaccharide	Yield
1	X = Br **(74)**	R_1 = $(CH_2)_8CO_2CH_3$ R_2 = NHAc R_3 = Ac R_6 = Bn **(89)**	AgOTf, TMU 3Å, sieves CH_2Cl_2, 0°C to rt	R_1 = $(CH_2)_8CO_2CH_3$ R_2 = NHAc R_6 = Bn **(92)**	Trace
2	X = O, CCl_3, NH **(75)**	R_1 = $(CH_2)_7CH_3$ R_2 = NHAc R_3 = Ac R_6 = TBS **(91)**	TMS-OTf, 3Å sieves, CH_2Cl_2, -20 °C	R_1 = $(CH_2)_7CH_3$ R_2 = NHAc R_6 = TBS **(93)**	37%
3	X = O, CCl_3, NH **(75)**	R_1 = $(CH_2)_7CH_3$ R_2 = NPht R_3 = Ac R_6 = TBS **(90)**	TMS-OTf, 3Å sieves, CH_2Cl_2, -20 °C	R_1 = $(CH_2)_7CH_3$ R_2 = NPht R_6 = TBS **(94)**	Trace
4	X = O, CCl_3, NH **(75)**	R_1 = $(CH_2)_7CH_3$ R_2 = NPht R_3 = H R_6 = TBS **(87)**	1. $BF_3{\cdot}OEt_2$, 3Å sieves, CH_2Cl_2, -50 °C 2. Ac_2O, pyr.	R_1 = $(CH_2)_7CH_3$ R_2 = NPht R_6 = Ac **(94)**	55% (2 steps)
5	X = O, CCl_3, NH **(75)**	R_1 = $(CH_2)_7CH_3$ R_2 = NPht R_3 = H R_6 =TBS **(87)**	1. TMS-OTf, 3Å sieves, CH_2Cl_2, -20 °C 2. Ac_2O, pyr.	R_1 = $(CH_2)_7CH_3$ R_2 = NPht R_6 = TBS **(95)**	22% (2 steps)

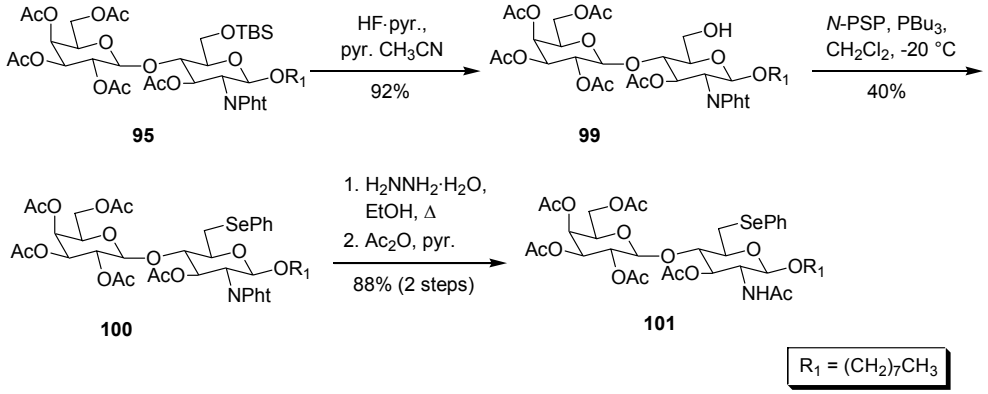
In order to evaluate the N-PSP reagent for installation of the C-6 phenylselenide, a model reaction was performed on a simple C-6 alcohol (Scheme 4.4). The octyl glycoside **87** was O-acetylated to form **96** and the C-6 TBS ether removed with HF·pyridine to give the C-6 alcohol, **97**. The C-6 phenylselenide, **98**, was successfully formed in moderate yield using *N*-PSP and PBu_3 conditions. [46]

Scheme 4.4



The β-1, 4 C-6 phenylselenide glycoside was then formed using the same conditions (Scheme 4.5) as described in Scheme 4.4. The C-6 –OH, **99**, was formed in a 92% yield, but tconversion to the selenide **100** proceeded in poor yield. Removal of the phthaloyl and acetyl protecting groups, followed by N- and O-acetylation produced **101**.

Scheme 4.5

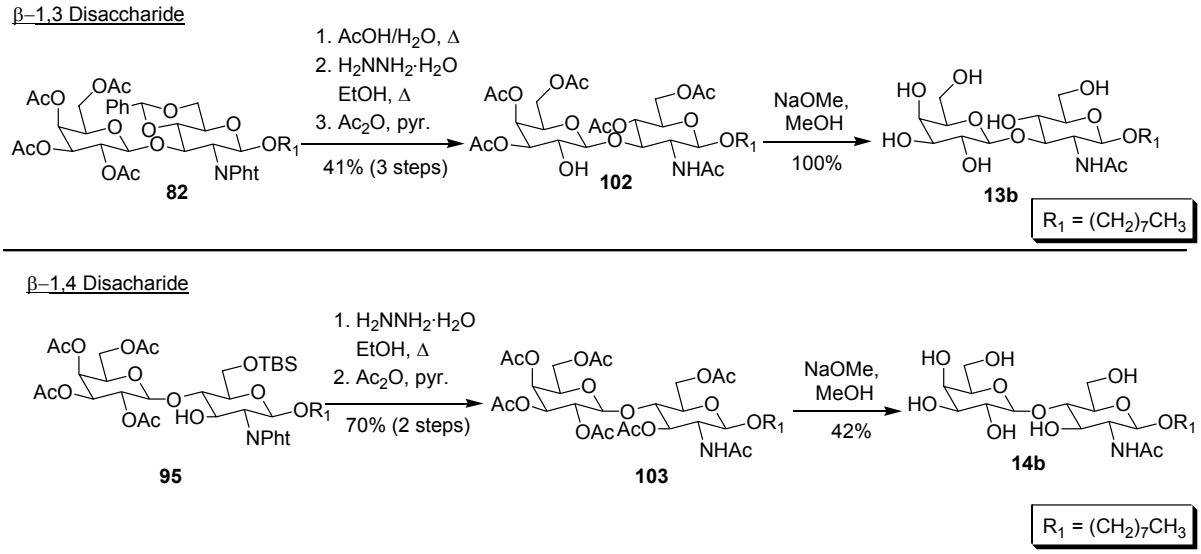


4.4 Synthesis of non-fluorinated (iso)LacNAc-octyl glycosides

After formation of the desired β glycosidic linkages **82** and **95**, the remaining protecting groups were removed in order to provide the non-fluorinated alternate substrates **13b** and **14b** (Scheme 4.6). The TBS ether at C-6 of **95** was removed during

hydrazinolysis. This has not been previously reported in the literature and is a new method for removing primary TBS ethers.

Scheme 4.6



The non-fluorinated substrates were synthesized in order to compare the fluorinated versus non-fluorinated substrates with the FucT III enzyme. The octyl side chain was installed for the Sep-Pak assay used to evaluate the FucT III enzymatic reaction (Figure 4.4).[74] The glycosides with the octyl side chain adhere to the reverse-phase column when eluted with water, washing away water-soluble impurities. Methanol is then used to remove the octyl glycosides from the column, allowing recovery and analysis of the trisaccharide product. Compounds **13b** and **14b** have been submitted to our collaborator, Hans Lin, for evaluation with the FucT III enzyme.

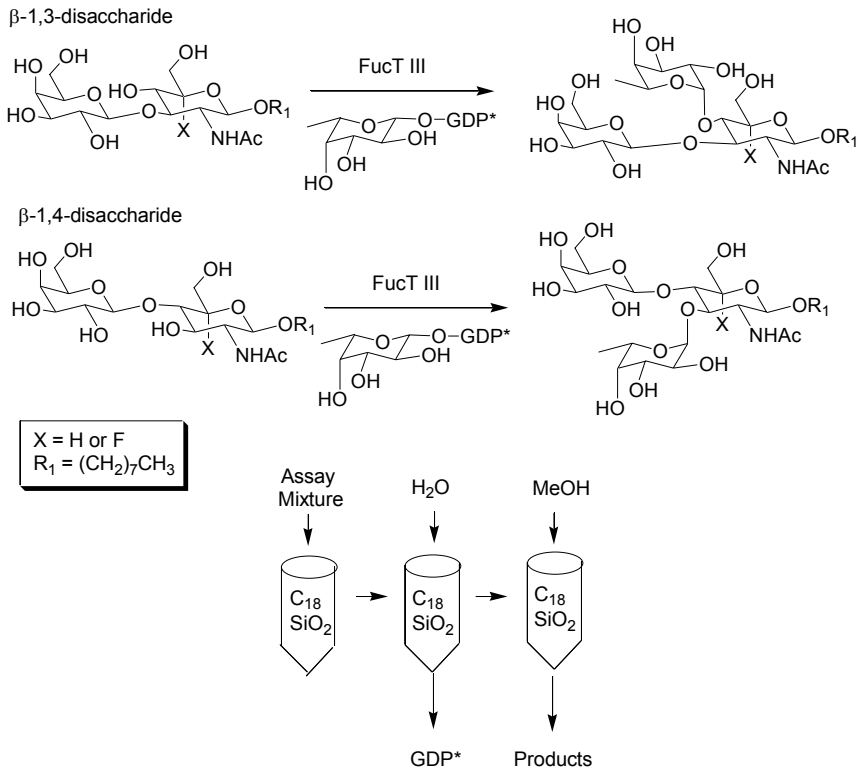


Figure 4.4: Sep-Pak Assay

4.5 Conclusions

Both the β-1, 3 and β-1, 4 C-6 phenylselenide containing glycosides **85** and **101** were successfully synthesized by converting the non-selenium containing glycosides **82** and **95** to the C-6 selenium-containing glycosides. In contrast, attempts at glycosylation with phenylselenide-containing monosaccharide acceptor substrates were unsuccessful in disaccharide formation. Glycosylation reactions containing a C-6 phenylselenide containing acceptor have not been reported in the literature and Table 4.1 and **Error! Reference source not found.** provide the first evidence that C-6 phenylselenide monosaccharide acceptor substrates are not synthetically viable as acceptor substrates for glycosylation reactions. This problem can be overcome be converting the non-selenium containing glycosides to the C-6 phenylselenide glycosides as shown in

Table 4.3 and Table 4.4.

In addition to the C-6 phenylselenide glycosides, the non-fluorinated alternate substrates **13b** and **14b** were also synthesized. Although these glycosides have been

previously reported in the literature, the new strategy presented in Section 4.4 is accessed from the readily available non-selenium containing disaccharides and is divergent to the C-6 phenylselenide-containing glycosides.

CHAPTER 5

SYNTHESIS OF 5, 6 EPOXY GLYCOSIDES AND GLYCOSYL PHOSPHATES

5.1 Introduction

5, 6 Epoxide installation is performed in a three-step process from the C-6 phenylselenides **42a**, **42b**, **71a**, **71b**, **63**, **69**, **85** and **101**. The role of the axial C-4 substituent on the stability of 5, 6 epoxy GalNAc glycosides is of interest as this substituent will be adjacent to the 5, 6 epoxide. Both electron-withdrawing and electron-donating protecting groups have been investigated at the C-4 position to understand the role of the C-4 substituent on epoxide stability.

Oxidization of the phenylselenide to the selenoxide and thermal eliminatation in the presence of dihydropyran (DHP) provides the corresponding olefin (Figure 1.8). Epoxidation will be achieved using dimethyldioxirane (DMDO) because of the ease of removal of the by-product, acetone (Figure 5.1). Purification should be simplified because DMDO and acetone are easily removed by concentration *in vacuo*. The oxidant DMDO is synthesized from its parent ketone, acetone, and oxone in a $NaHCO_3$ solution.[75] This reaction is pH-sensitive because of the peroxymonosulfate dianion generated during the course of the reaction. If the pH is too low, the peroxymonosulfate dianion concentration falls, causing the reaction to slow. If the pH is too high, the

peroxymonosulfate dianion will attack the dioxirane to yield the parent ketone, O_2, and sulfate.[76]

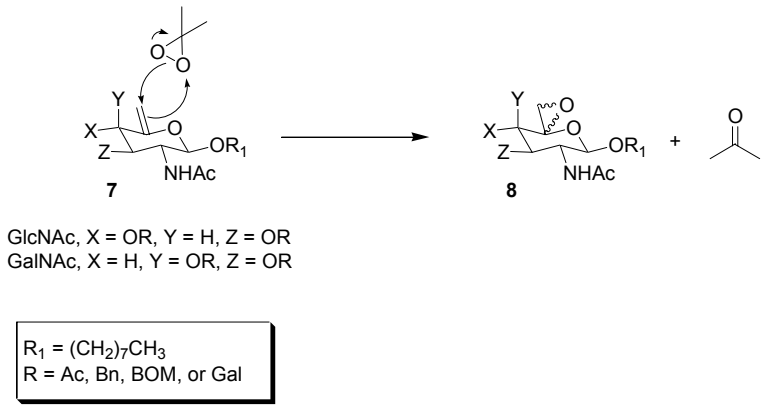


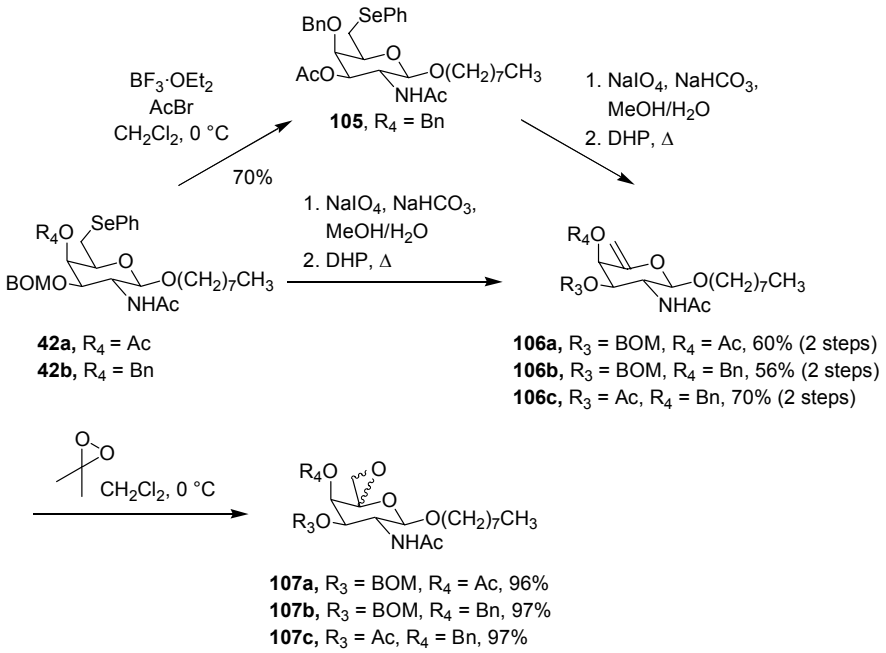
Figure 5.1: DMDO Epoxidation Reaction

5.2 Synthesis of 5, 6 GalNAc-β-octyl glycoside epoxides

The phenylselenide-containing compounds **42a** and **42b** were oxidized to the selenoxide and thermally eliminated to give **104a** or **104b** (Scheme 5.1). Alternatively, the BOM group was selectively removed and the resulting free alcohol protected as an acetate using $BF_3{\cdot}OEt_2$ and AcBr to give **105**. The oxidation and elimination were performed for both R_4 = Ac and Bn. When R_4 = Ac, the olefin, **106a**, was found to be more stable than R_4 = Bn, **106b** and **106c**. (The same trend was observed with the 5, 6 epoxides **107a-c**, where R_4 = Ac stabilized the epoxide.) When R_4 = Bn, a yellow color was observed with both the olefin and epoxide after standing a few hours in a NMR tube. Therefore the reaction sequence was performed quickly to avoid decomposition. Use of R_4 as an acetyl protecting group was theorized to help stabilize the olefin due to its electron-withdrawing nature. A 3:2 ratio of epoxide glycosides was observed for the C-4

OAc epoxide **107a**, but the ratio was not determined for the C-4 benzyl ether glycosides, **107b** and **107c**.

Scheme 5.1

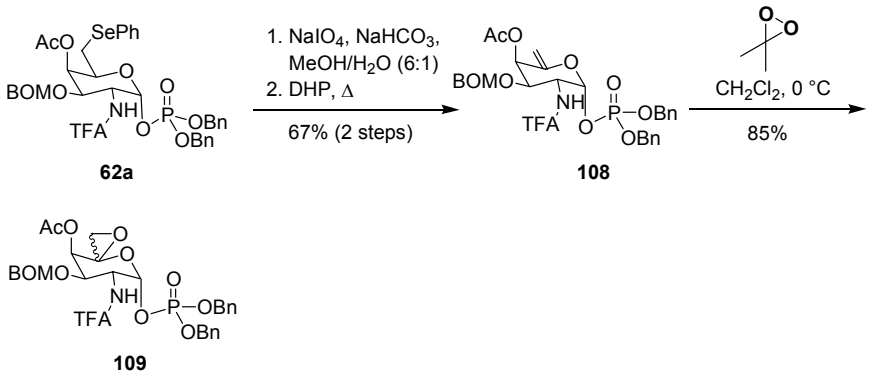


Submission of the epoxides for HRMS analysis resulted in decomposition of the epoxides. As a result, the formation of the olefins and epoxides in the reaction sequences were performed quickly to avoid formation of any potential decomposition products.

5.3 Synthesis of 5, 6 GalNAc phosphate epoxides

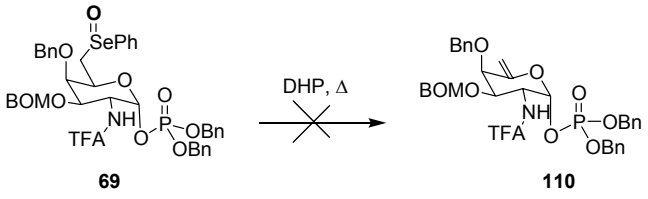
The glycosyl phenylselenide phosphate, **62a**, was oxidized to the selenoxide and eliminated to form the olefin **108** (Scheme 5.2). The olefin was transformed to the epoxide, **109**, with DMDO. The C-4 acetate glycosyl phosphate epoxide was formed in a 3:2 ratio of epoxides, similar to the β-octyl glycoside epoxide **107a**.

Scheme 5.2



In contrast, attempts at formation of the C-4 Bn galactosyl phosphate olefin **110** were not successful (Scheme 5.3). Loss of the ^{31}P NMR signal was observed after elimination of the selenoxide was attempted. Given the instability of the C-4 Bn octyl glycosides **106b** and **106c**, it is not surprising that the olefin **110** was not stable since the phosphate is a better leaving group than octanol.

Scheme 5.3



It is proposed that the electron-donating benzyl ether enhanced nucleophilicity of the putative vinyl ether **110**, resulting in protonation of the olefin and formation of a carbocation at C-5, which could be stabilized by the ring oxygen. Quenching of the carbocation with H_2O upon aqueous work-up could result in opening of the carbohydrate,

leading to loss of the phosphate leaving group at C-1 and decomposition (Figure 5.2). Synthesis of the the C-4 Bn glycosyl phosphate, **110**, was not pursued further.

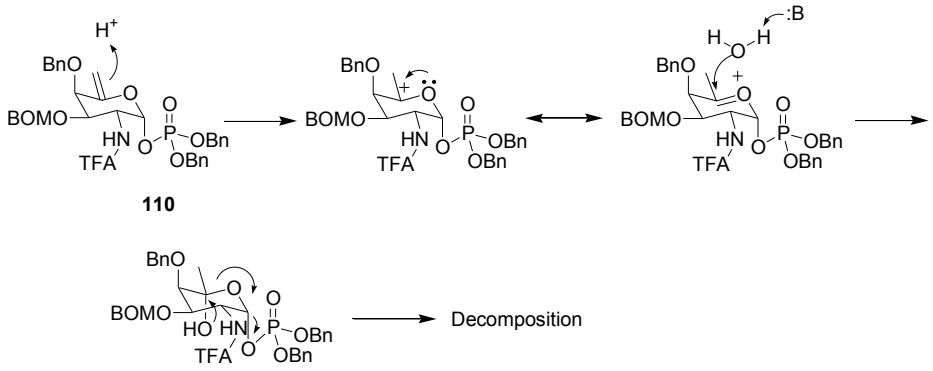
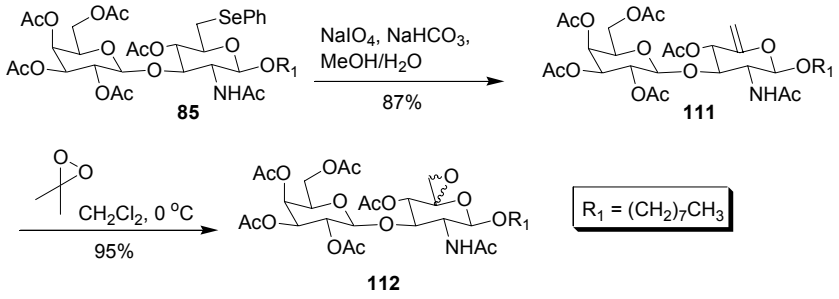


Figure 5.2: Hypothesis for Decomposition of **110**

5.4 Synthesis of isoLacNAc-octyl glycoside epoxide

In the case of the β-1, 3 isoLacNAc-octyl glycoside alternate substrate, spontaneous loss of the selenoxide to the olefin was observed during the course of the oxidation (Scheme 5.4). If the reaction time was extended, complete elimination to the olefin was observed eventually giving an 87% yield. If the reaction was stopped before complete oxidation to give the selenoxides, DHP elimination of the selenoxides resulted in a 63%, 2-step yield. If the elimination went longer than necessary (over 1 hour), removal of the acetates was observed. The resulting free alcohols could then be re-protected with acetic anhydride and pyridine to form **111** without causing decomposition. The epoxide **112** was formed in excellent yield with a 1:1 diastereomeric ratio. Though the epoxides would decompose upon submission of HRMS, nominal mass spectra could be obtained on the epoxides if obtained immediately upon work-up.

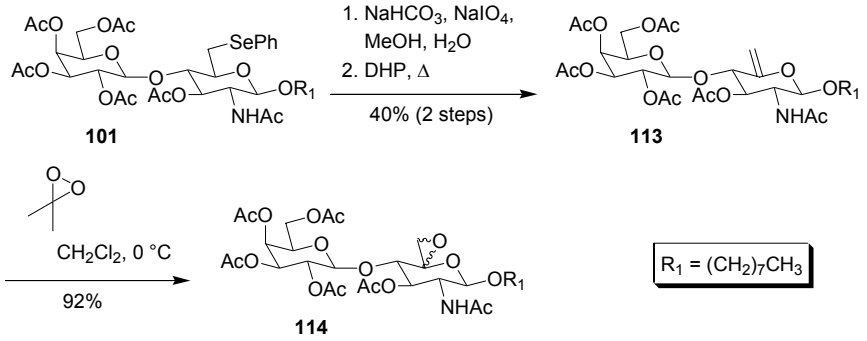
Scheme 5.4



5.5 Synthesis of LacNAc-octyl glycoside epoxide

The same spontaneous loss of the selenoxides with direct formation of the olefin that was described in the previous section was also observed in the β-1, 4 disaccharide. However, complete conversion to the olefin was not observed. Therefore, the remaining selenoxides were thermally eliminated with DHP to afford the olefin **113** (Scheme 5.5). The epoxidation proceeded in good yield to give **114** as one diastereomer.

Scheme 5.5

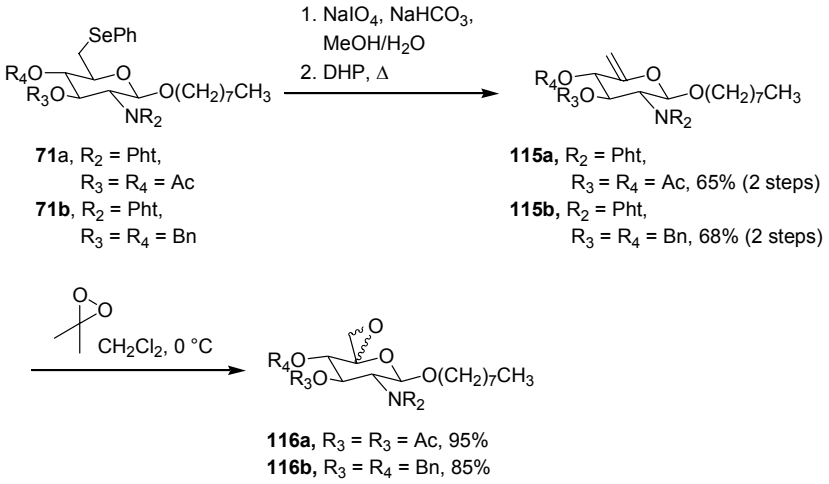


5.6 Synthesis of glucosaminyl epoxides for attempts at cyanosilylation

The phenylselenides **71a** and **71b** were oxidized using $NaIO_4$ to form their corresponding selenoxides (Scheme 5.6). The resulting selenoxides were then converted

to the olefins **115a** and **115b** by thermal elimination with DHP. The olefins were then treated with DMDO to afford their corresponding epoxides, **116a** and **116b**, both in a 3:2 diastereomeric ratio.

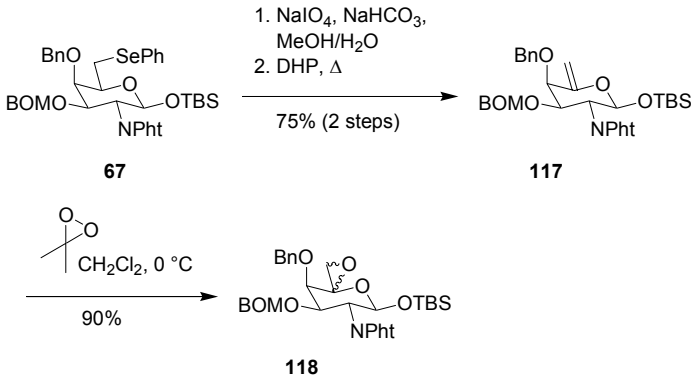
Scheme 5.6



5.7 Synthesis of galactosaminyl epoxides for attempts at cyanosilylation

In addition to synthesizing the epoxides **116a** and **116b**, the epoxide **118** was also investigated. The galactosyl phenylselenide, **67**, used was previously described in Chapter 3, Scheme 3.10. The phenylselenide was oxidized to its corresponding selenoxide and then thermally eliminated with DHP to form the olefin **117** (Scheme 5.7). Glycoside **117** was transformed to the epoxide **118** in good yield; however the diastereomeric ratio was undeterminable.

Scheme 5.7



5.8 Conclusions

The GalNAc, GlcNAc and (iso)LAcNAc C-6 phenylselenide-containing glycosides were successfully transformed to their corresponding epoxides **107**, **109**, **112, 114**, **116** and **118**. In the case of the GalNAc-octyl glycosides and GalNAc-α-phosphates, an electron-withdrawing C-4 substituent formed a stable olefin and epoxide in a 3:2 diastereomeric ratio. Use of an electron-donating protecting group at C-4 led to an unstable olefin and epoxide, resulting in the need to proceed quickly through the reaction sequence.

CHAPTER 6

ATTEMPTS AT EPOXIDE FLUORIDOLYSIS AND CYANOSILYATION

6.1 Introduction

Epoxide fluoridolysis is achieved by using HF·pyridine which protonates the epoxide, and then allows the nucleophilic fluoride to attack, opening the epoxide[77]. It is uncertain what effect an axial C-4 substituent will have on the GalNAc epoxide fluoridolysis. (5-fluoro) GalNAc glycosides have not been reported in the literature and our epoxide fluoridolysis methodology will be attempted on the GalNAc epoxides (**8**) previously described. (5-fluoro) (iso)LacNAc glycosides have not been described in the literature and this thesis presents the first attempts at epoxide fluoridolysis on β-1, 3 and β1-, 4 glycoosides. After fluoridolysis, the protecting groups can then be removed to form the desired 5-fluoro glycosides (Figure 6.1).[8]

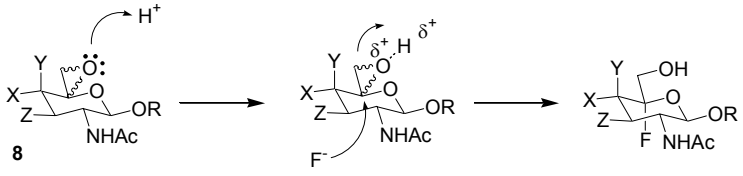
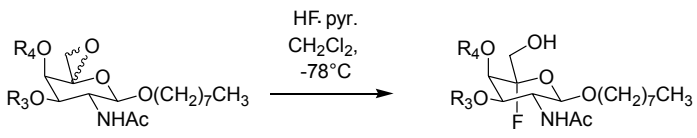


Figure 6.1: Epoxide Flouridolysis

6.2 Attempts at synthesis of (5-F) GalNAc-β-octyl glycosides

When epoxide fluoridolysis was completed on **107a**, **107b** and **107c**, decomposition was observed when R_4 = Ac (Scheme 6.1). When R_4 = Bn, as in **107b** and **107c**, fluoridolysis was successful and formed the desired C-F bond at C-5. However, the (5-F) GalNAc glycosides were unstable and decomposed upon purification on silica gel. Attempts at neutralizing the silica gel with 2% NEt_3 in the column eluent did not improve the stability of the (5-F) glycosides.

Scheme 6.1



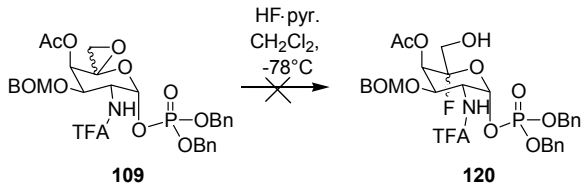
107a, R_3 = BOM, R_4 = Ac
107b, R_3 = BOM, R_4 = Bn
107c, R_3 = Ac, R_4 = Bn

119a, R_3 = BOM, R_4 = Ac, decomposition
119b, R_3 = BOM, R_4 = Bn, isolated small amount (^1H, ^{19}F NMR, MS)
119c, R_3 = Ac, R_4 = Bn, isolated small amount (^1H,^{19}F NMR, MS)

6.3 Attempts at the synthesis of UDP (5-F) GalNAc

When epoxide fluoridolysis was attempted on **109** using HF·pyridine, loss of the C-1 phosphate peak was observed according to ^{31}P NMR (Scheme 6.2). There was also only one fluorine peak according to ^{19}F NMR, corresponding to the N-TFA group. As described above, the same results as the GalNAc-β-octyl glycoside was observed when there was a C-4 acetate protecting group, **107a** to **119a**.

Scheme 6.2



6.4 Premature epoxide opening hypothesis

The hypothesis for the decomposition observed with the C-4 aceto-glycoside, **107a**, and glycosyl phosphate, **109**, is that premature epoxide opening occurred via anchiomeric assistance of the axial C-4 aceto substituent (Figure 6.2).

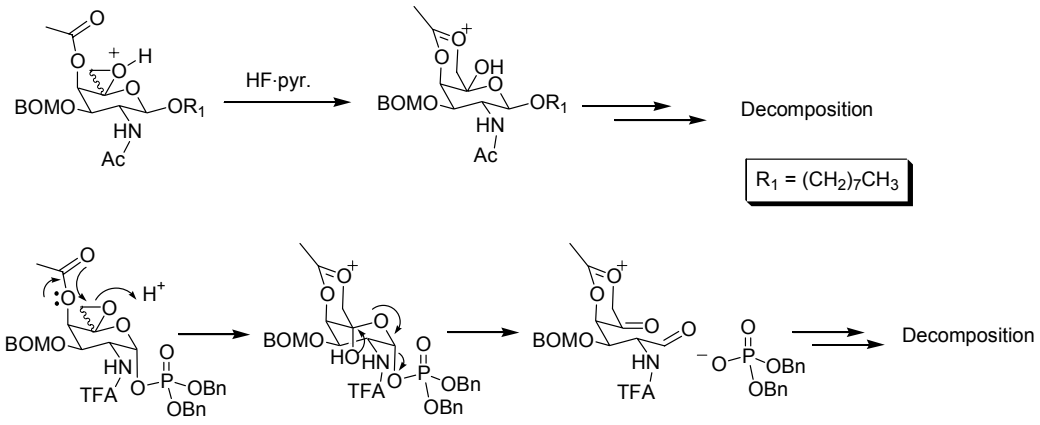
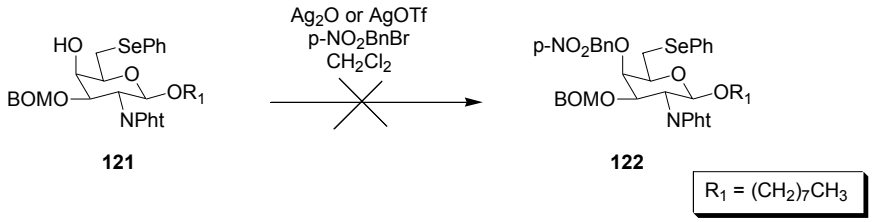


Figure 6.2: Premature Epoxide Opening Hypothesis

This decomposition seemingly can be avoided by having a non-participatory protecting group at the C-4 position, such as benzyl, as observed with the glycosyl epoxides **118b** and **118c**. However, the electron-donating benzyl ether does not seem to be able to stabilize the epoxide as well as the electron-withdrawing C-4 acetate. Perhaps use of an electron-withdrawing and non-participatory protecting group may help stabilize

the epoxide and allow for fluoridolysis. Repeated attempts of using a p-nitrobenzylbromide and a silver salt promoter[78] resulted in decomposition of the model substrate **121**, perhaps due to the nucleophilic nature of the selenium (Scheme 6.3). An alternative to the p-nitrobenzylbromide would be to use ClAc at C-4. ClAc is an electron-withdrawing protecting group, but potentially would not be involved in premature epoxide opening due to its reduced nucleophilicity of the electron-withdrawing Cl.

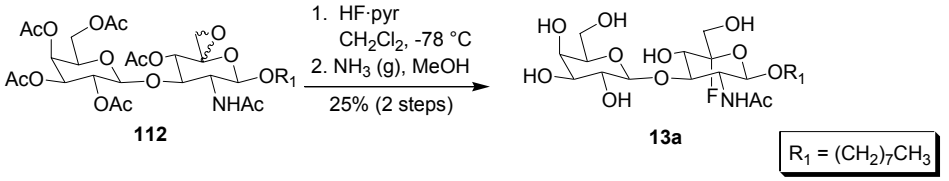
Scheme 6.3



6.5 Synthesis of (5-F) isoLacNAc-octyl glycoside

Since the β-1, 3 and β-1, 4 disaccharides do not have an axial C-4 substituent, there should not be any neighboring group participation and epoxide fluoridolysis should proceed similarly to the GlcNAc series. In the case of the (5-F) isoLacNAc-octyl glycoside, epoxide fluoridolysis on **112** was achieved using HF·pyridine and the remaining acetate protecting groups were removed with methanolic ammonia to give **13a**, X = F (Scheme 6.4).

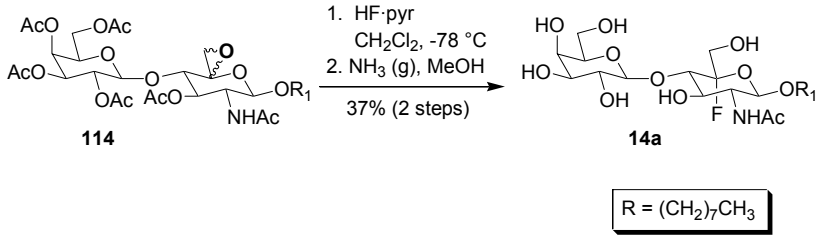
Scheme 6.4



6.6 Synthesis of (5-F) LacNAc-octyl glycoside

Synthesis of the (5-F) β-1, 4 octyl glycoside proceeded similarly as the β-1, 3 octyl glycoside (Scheme 6.5). After epoxide fluoridolysis on the epoxide **114**, the O-Ac protecting groups were removed to afford **14a**, X = F.

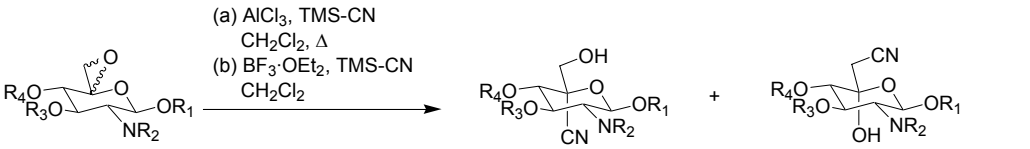
Scheme 6.5



6.7 Synthesis of 5, 6 glucosaminyl cyano sugars

The glucosaminyl epoxides **116a**, **116b** and **123**[8] were transformed to the 5-(CN), 6-(OH) sugars, **124a**, **124b** and **124c**, and 5-(OH), 6-(CN) sugars, **125a, 125b** and **125c**, using either $AlCl_3$ or $BF_3{\cdot}OEt_2$ as the Lewis acid activator (Scheme 6.6). Both Lewis acids produced the desired cyano glycosides, however use of $AlCl_3$ in general proceeded with fewer undesired side products.

Scheme 6.6



116a, $R_1 = (CH_2)_7CH_3$, R_2 = Pht, $R_3 = R_3$ = Ac
116b, $R_1 = (CH_2)_7CH_3$, R_2 = Pht, $R_3 = R_4$ = Bn
123, $R_1 = (CH_2)_7CH_3$, R_2 = HAc, $R_3 = R_4$ = Ac

124a, $R_1 = (CH_2)_7CH_3$, R_2 = Pht, $R_3 = R_3$ = Ac, (a) 21%, (b) 27%
124b, $R_1 = (CH_2)_7CH_3$, R_2 = Pht, $R_3 = R_4$ = Bn, (a) 35%, (b) 10%
124c, $R_1 = (CH_2)_7CH_3$, R_2 = HAc, $R_3 = R_4$ = Ac, (a) 33%

125a, $R_1 = (CH_2)_7CH_3$, R_2 = Pht, $R_3 = R_3$ = Ac, (a) trace, (b) trace
125b, $R_1 = (CH_2)_7CH_3$, R_2 = Pht, $R_3 = R_4$ = Bn, (a) trace, (b) trace
125c, $R_1 = (CH_2)_7CH_3$, R_2 = HAc, $R_3 = R_3$ = Ac, (a) trace

The regiochemistry of this reaction has been determined qualitatively using a 2, 4 dinitrophenylhydrazine (DNP) TLC spray (Figure 6.3). If there is a free alcohol at the C-5 position, then the glycoside exists as a reducing sugar in the open and closed forms of the carbohydrate. As a result, the glycoside has a ketone and is DNP-positive. If there is a cyano group at C-5, there is no ketone and therefore should be DNP-negative. The DNP results show that the major product formed was not DNP-positive. A minor product visible by TLC produced a faint DNP-positive stain, indicating formation of the (5-hydroxyl) glycoside in trace amounts.

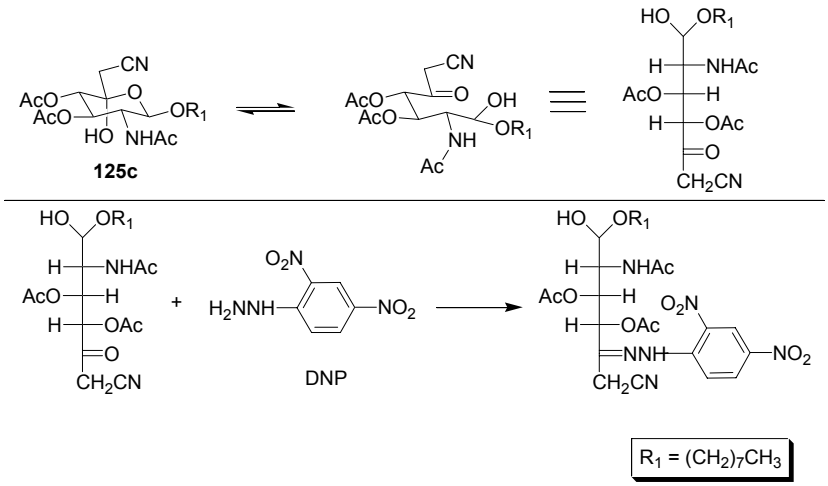
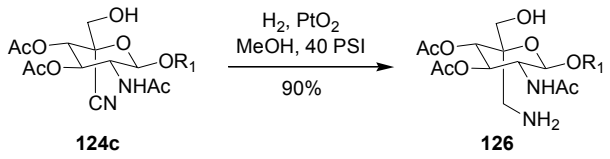


Figure 6.3: Determination of C-5 Regioselectivity of (5-Cyano) Glycosides

After formation of the (5-cyano) glycosides, the CN group of **124c** was reduced using H_2 and PtO_2 in MeOH to give the free amine **126** (Scheme 6.7). The amino group could then be potentially coupled to biotin or other compounds useful for assaying carbohydrates. These new glycosides could be useful as mechanistic probes of carbohydrate metabolizing enzymes.

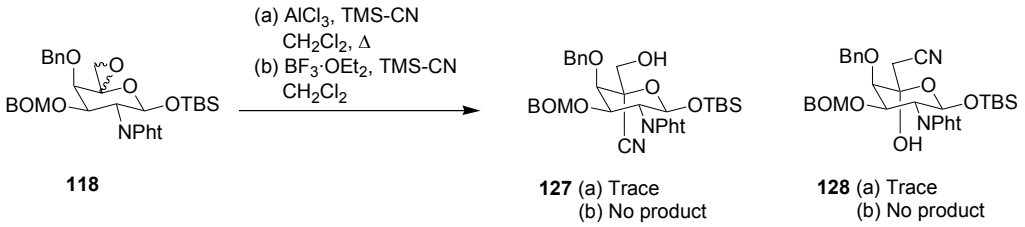
Scheme 6.7



6.8 Attempted synthesis of 5, 6 galactosaminyl cyano sugars

In the case of the TBS glycoside **118**, use of $AlCl_3$ resulted in a small amount of product formed by mass spectrum analysis, but mostly resulted in undesired side products (Scheme 6.8). Use of $BF_3{\cdot}OEt_2$ on **118** resulted only in formation of undesired side products.

Scheme 6.8



6.9 Conclusions

The GalNAc glycoside epoxides **107b** and **107c** successfully underwent epoxide fluoridolysis to form the (5-fluoro) GalNAc glycosides **119b** and **119c**. However, use of the C-4 acetate epoxide **107a**, resulted in premature epoxide opening of the glycoside, presumably by neighboring group participation (Figure 6.2). This same trend was observed with the GalNAc glycosyl phosphate **120**. It is noteworthy that the electron-withdrawing C-4 acetate had a stabilizing effect on the epoxide, whereas the electron-donating C-4 benzyl ether did not produce a stable epoxide.

Neighboring group participation was not observed in the (iso)LacNAc series as there is no axial C-4 substituent. The (5-fluoro) (iso)LacNac glycosides **13a** and **14a** were successfully synthesized.

In addition to epoxide fluoridolysis, attempts at a new C-C bond formation at C-5 were attempted using the GlcNAc and GalNAc epoxides **116a**, **116b**, **118** and **123**. The cyanosilylation successfully produced the desired (5-cyano) GlcNAc glycosides. The new method was amenable with electron-withdrawing and electron-donating protecting groups such as acetate and benzyl ethers. However, use of the GalNAc epoxide **118**

resulted in decomposition of the glycoside, perhaps due to the reactivity of the TBS ether and the strong Lewis acids $AlCl_3$ and $BF_3 \cdot OEt_2$. A more stable group at C-1, such as a GalNAc-octyl glycoside could be used. This would allow for comparison of the more labile C-F bond at C-5 to a more stable C-C bond at C-5.

CHAPTER 7

CONCLUSIONS

7.1 Synthesis of C-6 phenylselenide-containing monosaccharides and disaccharides

In conclusion, the C-6 phenylselenide monosaccharide glycosides were synthesized from the key benzylidene intermediate, **32**. Several orthogonally protected phenylselenide glycosides were obtained in order to investigate the effect of electron-withdrawing versus electron-donating protecting groups at C-2, C-3 and C-4 during glycosylation reactions, epoxide fluoridolysis, and cyanosilylation reactions. Phenylselenide-containing β-octyl-glycosides and α-phosphates were synthesized as precursors to the fluorinated acceptor and donor substrates for the glycosyltransferases of interest.

In pursuit of the β-1, 3 and β-1, 4 disaccharides, the C-6 phenylselenide-containing monosaccharide glycosides were not acceptor substrates for formation of the selenium-containing glycosides (Table 4.1 and **Error! Reference source not found.**), presumably due to the selenium acting as a competitive nucleophile (**Error! Reference source not found.**). Fortunately, the C-6 phenylselenide-containing (iso)LacNAc-octyl glycosides were readily obtained by installing the selenium after disaccharide formation.

7.2 Synthesis of 5, 6 GalNAc, GlcNAc and (iso)LacNAc epoxides

Oxidation of the C-6 phenylselenide-containing glycosides to their corresponding selenoxides, followed by thermal elimination in the presence of DHP

produced the desired GalNAc, GlcNAc and (iso)LacNAc olefins. Epoxidation proceeded in good to excellent yields. In general, the GalNAc epoxides were formed in a 3:2 diastereomeric ratio. The GlcNAc and isoLAcNAc epoxides were formed in a 1:1 diastereomeric ratio, whereas the LacNAc epoxide was a single diastereomer. The role of electron-withdrawing versus electron-donating protecting groups was investigated in the stability of the olefins and epoxides. Stability of the olefins and epoxides was enhanced with the use of an electron-withdrawing protecting group at C-4. In contrast, an electron-donating protecting group at C-4 resulted in a more labile olefin and epoxide. In the case of the C-4 Ac GalNAc α-phosphate, formation of the olefin and epoxides proceeded in good yields. However, the C-4 Bn GalNAc α-phosphate olefin was unstable and resulted in decomposition.

7.3 Attempts at epoxide fluoridolysis and cyanosilylation

The role of participating versus non-participating protecting groups was investigated during attempts at epoxide fluoridolysis. In the GalNAc series, an axial electron-withdrawing C-4 acetate resulted in premature epoxide opening from neighboring group participation of the axial C-4 acetate (Figure 6.2). With a non-participatory protecting group at C-4, such as benzyl ether, the fluoridolysis was successful. However, the (5-fluoro) GalNAc glycosides were unable to be purified due to instability. In the future, an electron-withdrawing, non-participatory protecting group at C-4 may allow for stable C-F bond formation at C-5.

In pursuit of the β-1, 3 and β-1, 4 disaccharides, epoxide fluoridolysis was successful, allowing for potential evaluation of the FucT III glycosyltransferase. Since there was no axial C-4 substituent adjacent to the 5, 6 epoxides, therefore no premature epoxide opening was observed. Compounds **13a**, **13b**, **14a** and **14b** will be sent to our

collaborator Hans Lin at the Academia Sinica, Taiwan for biochemical evaluation with the FucT III enzyme. It will be interest to see if **13a** and **14a** will be substrates for FucT III and what effect fluorine has on glycosylation catalyzed by FucT III.

In addition to the formation of (5-fluoro) glycosides, the GlcNAc 5, 6 epoxides were subjected cyanosilylation conditions to form predominantly give the (5-cyano) glycosides. In the GalNAc series, only trace amounts of a cyano glycoside was detected by mass spectrum analysis. It is proposed that the TBS ether is not compatible with the strong Lewis acid conditions and resulted in decomposition. Perhaps use of an octyl glycoside at C-1 would allow for formation of a (5-cyano) GalNAc glycoside.

The CN group allowed access to the free amine, which may be coupled to biotin, fluorocene, KLH, peptides and other synthons used in evaluating glycosyltransferase reactions. Additional future work on the (5-cyano) glycosides should include optimization of the reaction conditions to improve yields, as well as further investigation of functional group tolerance. Overall, the cyanosilylation reaction is a promising new method for installing a carbon substituent at the C-5 position of carbohydrates.

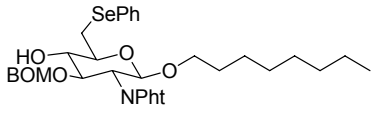
CHAPTER 8

EXPERIMENTAL

General Experimental: All chemicals used were from Aldrich or Acros, except for BOM-Cl from TCI America and 8-methoxycarbonyl octanol from TRC. Water-sensitive reactions were conducted under an argon atmosphere and used oven-dried glassware, syringes and needles. Solvents were freshly distilled for moisture-sensitive reactions: THF from benzophenone ketyl, MeOH, NEt_3, CH_2Cl_2 and pyridine from CaH_2. $CHCl_3$ was purified by passing through a column of activated Al_2O_3. AgOTf was purified by azeotropic removal of impurities with toluene. Flash column chromatography used 230-400 mesh Whatman silica gel. TLC was run on Whatman 250 μm silica plates with UV fluorescence detected by short wave UV. ^1H and ^{13}C NMR spectra were recorded on a Bruker Avance DRX-500 or 300 spectrometers or Varian 300 or 400 spectrometers. ^1H NMR chemical shifts (δ) for $CDCl_3$ or CD_3OD are in ppm using TMS as the reference at 0.00 ppm. ^1H NMR chemical shifts (δ) for spectra obtained in D_2O were referenced to HOD at 4.79 ppm. ^{13}C NMR chemical shifts (δ) for $CDCl_3$ or CD_3OD are in ppm using the center solvent peak of $CDCl_3$ at 77.00 ppm as the reference and CD_3OD at 49.00 ppm as the reference. ^{19}F NMR chemical shifts were referenced to TFA at 0 ppm as an external standard to TFA in $CDCl_3$. NMR assignments were based upon ^1H J values, ^1H COSY and HETCOR. Diastereomeric ratio of 5, 6 epoxides were determined by ^1H

NMR analysis. Mass spectra were recorded on a Micromass LCT Time-of-Flight mass spectrometer by electrospray ionization using sodium as the ion. Tetrabenzylpyrophosphate (TTBP) was prepared as described.[79] Dimethyldioxirane was prepared as described.[75] Compounds **43,**[80] **44,**[51] **46,**[38] **74,**[81] **75,**[81] **86,**[47] **91,**[73] were synthesized according to the literature procedures. Compound **32**[47] to **34**[8] was synthesized following modified procedures based upon the work of Matt Hartman, where the bromide was displaced first with phenylselenol before BOM protection at C-3. Compound **48** was purchased from Aldrich. Compound **76** and **77** were in spectral agreement with the literature.[82] Compounds **76-80** were synthesized from modified literature procedures. Compound **78** was in spectral agreement with the literature.[80] Compound **80** was in spectral agreement with the literature.[63] Compound **102** was in spectral agreement with the literature.[83]

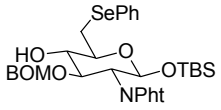
Octyl 3-*O*-[(benzyloxy)methyl]- 2, 6-dideoxy-2-phthalamido-6-phenylseleno-∃-D-glucopyranoside (35a).



To a stirred solution of **34a**[8] (1.90 g, 2.42 mmol) in 100 mL of THF:MeOH (1:1) was added 0.5M NaOMe solution (0.28 mL, 5.32 mmol). An additional portion (0.28 mL, 5.32 mmol) of the NaOMe solution was added after 17 h. After 45 h, the reaction was quenched with 2.0 g of Dowex 50W H^+ form resin (2.1 meq/mL) and stirred gently for 30 min. The mixture was filtered and the filtrate concentrated. The resulting oil was

purified by flash column chromatography (hexanes:EtOAc, 3:1) to afford **35a** as a colorless oil (1.47 g, 89%). ^{1}H NMR ($CDCl_3$) δ 7.71 (d, 2H, NPht), 7.60 (m, 2H, NPht), 7.14 (m, 5H, SePh), 7.08 (m, 3H, ArH of BOM), 7.00 (m, 2H, ArH of BOM), 5.07 (d, 1H, J = 8.3 Hz, H1), 4.74 (d, 1H, J = 7.1 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.58 (d, 1H, J = 7.1 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.50 (d, 1H, J = 12.0 Hz, -OH), 4.33 (s, 2H, O-C$\underline{H}_2$-O-Bn), 4.25 (d, 1H, J = 10.8 Hz, H4), 4.18 (dd, 1H, J = 8.3 Hz, H3), 3.69-3.62 (dd, 2H, H2/C$\underline{H}_2$-octyl), 3.49-3.42 (dd, 2H, H5/C$\underline{H}_2$-octyl), 3.31 (m, 1H, J = 13.2, 6.6 Hz,H6), 3.11 (m, 1H, J = 12.8, 8.3 Hz, H6), 1.32-1.31 (bs, 2H, C$\underline{H}_2$-octyl), 1.16-0.97 (bs, 10H, C$\underline{H}_2$-octyl), 0.88 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 171.00, 136.30, 133.93, 132.03, 131.52, 130.99, 128.87, 128.41, 127.92, 127.72, 126.45, 123.47, 123.01, 98.11, 96.06, 82.53, 75.46, 74.00, 70.31, 69.50, 60.26, 55.15, 31.54, 31.47, 29.68, 29.01, 25.70, 22.53, 22.48, 20.92, 14.09, 13.95. MS (ES, Na^+): m/z (relative intensity) 704.2 (100). HRMS (M + Na^+) calcd for $C_{36}H_{43}NO_7SeNa$, 704.2102; found 704.2103.

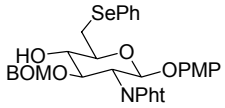
***t*-Butyldimethylsilyl- 3-*O*-[(benzyloxy)methyl]- 2, 6-dideoxy-2-phthalamido-6-phenylseleno-∃-D-glucopyranoside (35b).**



To a stirred solution of **34b**[8] (0.27 g, 0.340 mmol) in 10 mL of THF:MeOH (1:1) was added 1M NaOMe solution (0.35 mL, 0.35 mmol). After 6 h, the reaction was quenched with 0.75 g of Dowex 50W H^+ form resin (2.1 meq/mL) and stirred gently for 15 min. The mixture was filtered and the filtrate concentrated. The resulting oil was

purified by flash column chromatography (hexanes:EtOAc, 3:1) to afford **35b** as a colorless oil (0.20 g, 87%): ^{1}H NMR ($CDCl_3$) δ 7.89 (d, 2H, NPht), 7.79 (m, 2H, NPht), 7.62 (m, 2H, SePh), 7.37-2.28 (m, 8H, SePh/ArH of BOM), 5.42 (d, 1H, J = 7.8 Hz, H1), 4.93 (d, 1H, J = 6.0 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.73 (d, 2H, O-C$\underline{H}_2$-Ph/Bn/ O-C$\underline{H}_2$-O-Bn), 4.33 (s, 1H, O-C$\underline{H}_2$-O-Bn), 4.47 (d, 1H, J = 1.4 Hz, -OH), 4.40 (d, 1H, J = 10.9, 8.0 Hz, H3), 4.31 (dd, 1H, J = 10.8, 7.8 Hz, H2), 3.79 (dd, 1H,J = 9.0, 2.4 Hz, H4), 3.62 (m, 2H, J = 5,7, 3.0, 2.0 Hz, H5/H6), 3.24 (m, 1H, J = 12.6, 8.8 Hz, H6), 0.75-0.0.71 (bs, 9H, TBS), 0.13 (m, 3H, TBS) 0.08 (m, 3H, TBS). ^{13}C NMR ($CDCl_3$) δ 168.80, 167.99, 136.53, 134.25, 132.11, 131.32, 129.17, 128.65, 128.16, 127.96, 127.86, 126.97, 123.58, 123.22, 96.29, 93.63, 82.48, 75.60, 74.38, 70.51, 57.43, 60.26, 30.07, -3.89, -5.57. MS (ES, Na^+): m/z (relative intensity) 706.1 (100). HRMS (M + Na^+) calcd for $C_{34}H_{41}NO_7SeSiNa$, 706.1715; found 706.1723.

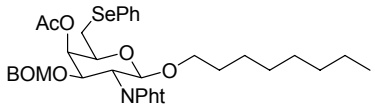
***p*-Methoxyphenyl- 3-*O*-[(benzyloxy)methyl]- 2, 6-dideoxy-2-phthalamido-6-phenylseleno-∃-D-glucopyranoside (35c).**



To a stirred solution of **34c**[8] (0.83 g, 1.23 mmol) in 100 mL of THF:MeOH (1:1) was added 1M NaOMe solution (0.35 mL, 0.35 mmol). After 21 h, the reaction was quenched with 1.75 g of Dowex 50W H^+ form resin (2.1 meq/mL) and stirred gently for 15 min. The mixture was filtered and the filtrate concentrated. The resulting oil was purified by flash column chromatography (hexanes:EtOAc, 2:1) to afford **35c** as a

colorless oil (0.53 g, 76%): ^{1}H NMR ($CDCl_3$) δ 8.01 (d, 2H, NPht), 7.75 (m, 2H, NPht), 7.63-7.48 (m, 5H, ArH of BOM), 7.29 (m, 2H, SePh), 7.10 (m, 3H, SePh), 6.84 (m, 2H, PMP), 6.72 (m, 2H, PMP), 5.58 (dd, 1H, J = 8.5 Hz, H1), 4.79 (d, 1H, O-C$\underline{H}_2$-Ph/Bn), 4.70-4.61 (m, 3H, H3/H4/ O-C$\underline{H}_2$-Ph/Bn), 4.49 (s, 2H, O-C$\underline{H}_2$-O-Bn), 4.33 (m, 1H, H2), 3.77 (dd, 1H, J = 9.0, 2.5 Hz, H5), 3.75 (s, 3H, OMe), 3.58 (dd, 1H, J = 8.5 Hz, H6), 3.16 (dd, 1H, J = 13.0, 8.5 Hz, H6). ^{13}C NMR ($CDCl_3$) δ 155.35, 150.78, 136.25, 134.17, 132.15, 129.10, 129.02, 128.53, 128.42, 128.09, 127.93, 127.86, 126.67, 118.65, 118.51, 114.35, 97.58, 96.14, 82.51, 75.60, 73.81, 70.48, 55.57, 55.03, 29.61. MS (ES, Na^+): m/z (relative intensity) 698.1 (100). HRMS (M + Na^+) calcd for $C_{35}H_{33}NO_8SeNa$, 698.1269; found 698.1264.

Octyl 4-*O*-acetyl-3-O-[(benzyloxy)methyl]-2, 6-dideoxy-2-phthalamido-6-phenylseleno- Ǝ-D-galactopyranoside (40a).

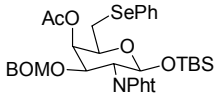


To a stirred -5 °C solution of **35a** (1.40 g, 2.06 mmol) in 60 mL of CH_2Cl_2 and pyridine (0.75 mL, 9.27 mmol) was added a freshly prepared solution of Tf_2O (0.69mL, 4.12 mmol) in 5 mL of CH_2Cl_2. The reaction solution turned a yellow-orange color with time and the temperature was maintained between -5 °C and +10 °C. After 2.25 h, the reaction was warmed to room temperature and diluted to 150 mL of CH_2Cl_2 and washed with 150 mL of satd. Cu_2SO_4, H_2O, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil (1.60 g) was taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.75 (d, 2H, NPht), 7.54 (m, 2H,

NPht), 7.24 (m, 2H, SePh), 7.08 (m, 3H, SePh), 6.85 (m, 5H, ArH of BOM), 5.11 (d, 1H, J = 8.4 Hz, H1), 4.83-4.76 (m, 2H, H3/H4), 4.72 (d, 1H, O-C$\underline{H}_2$-Ph/Bn), 4.62 (d, 1H, O-C$\underline{H}_2$-Ph/Bn), 4.32 (dd, 1H, J = 10.2, 8.4, Hz, H2), 4.15 (s, 2H, O-C$\underline{H}_2$-O-Bn), 4.92 (dd, 1H, J = 9.3, 3.0 Hz, H5), 3.70 (m, 1H, J = 9.9, 6.0 Hz, C$\underline{H}_2$-octyl), 3.38 (m, 1H, C$\underline{H}_2$-octyl), 3.29 (dd, 1H, J = 12.9, 2.7 Hz, H6), 3.15 (dd, 1H, J = 13.2, 9.3 Hz, H6), 1.43 (bs, 2H, C$\underline{H}_2$-octyl), 1.22-0.96 (bs, 10H, C$\underline{H}_2$-octyl), 0.80 (t, 3H, C$\underline{H}_3$-octyl). ^{19}F NMR ($CDCl_3$) δ 2.10. To the triflate glycoside was added a solution of Et_4NOAc (2.5 g, 9.85 mmol) in 25 mL of DMF. After 1 h, the reaction was concentrated to remove the DMF. The resulting red oil dissolved in 250 mL of CH_2Cl_2 and washed twice with 100 mL of H_2O and once with satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (hexanes:EtOAc, 3:1) to afford compound **40a** (1.25 g, 85%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.83 (d, 1H, NPht), 7.64 (m, 1H, NPht), 7.60 (s, 2H, NPht), 7.54 (m, 2H, SePh), 7.27 (m, 3H, SePh), 7.20 (m, 3H, ArH of BOM), 6.98 (m, 2H, ArH of BOM), 5.57 (d, 1H, J = 3.0 Hz, H4), 5.18 (d, 1H, J = 8.5 Hz, H1), 4.78 (d, 1H, J = 7.4 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.71 (dd, 1H, J = 11.0, 2.9 Hz, H3), 4.17 (s, 2H, J = 7.8 Hz, O-C$\underline{H}_2$-O-Bn), 4.11 (dd, 1H, J = 6.9 Hz, H2), 3.87 (dd, 1H, J = 7.0 Hz, H5), 3.81 (m, 1H, C$\underline{H}_2$-octyl), 3.40 (m, 1H, C$\underline{H}_2$-octyl), 3.19 (dd, 1H, J = 12.9, 7.7 Hz, H6), 3.00 (dd, 1H, J = 12.8, 5.9 Hz, H6), 2.18 (s, 3H, OAc), 1.26-1.23 (bs, 2H, C$\underline{H}_2$-octyl), 1.16-0.93 (bs, 10H, C$\underline{H}_2$-octyl), 0.81 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.57, 168.46, 167.63, 136.97, 133.95, 133.91, 132.85, 131.40, 131.34, 129.60, 129.18, 128.11, 127.35, 127.26, 127.09, 123.36, 122.98, 98.45, 92.82, 73.31, 71.56, 69.82, 69.49, 68.19, 60.28, 52.56, 31.53, 29.11, 29.00, 27.78, 25.68, 22.48, 20.95, 20.85, 14.10, 13.96, -0.92. MS (ES,

Na^+): m/z (relative intensity) 746.2 (100). HRMS (M + Na^+) calcd for $C_{38}H_{45}NO_8SeNa$, 746.2208; found 746.2232.

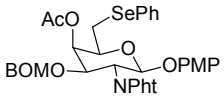
_t_-Butyldimethylsilyl, 4-_O_-acetyl, 3-_O_-[(benzyloxy)methyl], 2, 6-dideoxy-6-phenylseleno-2-phthlamido-β-D-galactopyranoside (40b).



To a stirred -5 °C solution of **35b** (0.065 g, 0.095 mmol) in 1.5 mL of CH_2Cl_2 and pyridine (0.030 mL, 0.428 mmol) was added a freshly prepared solution of Tf_2O (0.03 mL, 0.190 mmol) in 0.14 mL of CH_2Cl_2. The reaction solution turned a light pink color with time and the temperature was maintained between -5 °C and +10 °C. After 1 h, the reaction was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of satd. $NaHCO_3$ solution. The aqueous extract was washed with 5 mL of CH_2Cl_2 and the combined organic extracts washed with 10 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil (0.074 g) was taken on without any purification: ^1H NMR ($CDCl_3$) δ 7.88 (d, 2H, NPht), 7.59 (m, 2H, NPht), 7.35 (m, 2H, SePh), 7.15 (m, 3H, SePh), 6.91 (m, 5H, ArH of BOM), 5.40 (dd, 1H, J = 8.0 Hz, H1), 4.86-4.69 (m, 3H, H3/H4/H2), 4.67 (d, 2H, O-C<u>H</u>$_2$-Ph/Bn), 4.23 (s, 2H, O-C<u>H</u>$_2$-O-Bn), 3.98 (dd, 1H, J = 9.0 Hz, H5), 3.32 (dd, 1H, J = 12.7 Hz, H6), 3.19 (dd, 1H, J = 9.6 Hz, H6), 0.71 (s, 9H, tBu), 0.15 (s, 3H, Me), 0.06 (a, 3H, Me). ^{19}F NMR ($CDCl_3$) δ 1.78. To the triflate glycoside was added a solution of Et_4NOAc (0.18 g, 0.681 mmol) in 3 mL of DMF. After 15 min, the reaction was concentrated to remove the DMF. The crude product was dissolved in 50 mL of CH_2Cl_2 and washed twice with 25 mL of H_2O and once with satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate

concentrated. The crude product was purified with flash column chromatography (hexanes:EtOAc, 3:1) to afford **40b** (0.08 g, 87%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.86 (d, 1H, NPht), 7.70 (m, 1H, NPht), 7.65 (m, 2H, NPht), 7.53 (m, 2H, SePh), 7.31 (m, 3H, SePh), 7.22 (m, 3H, ArH of BOM), 7.02 (m, 2H, ArH of BOM), 5.54 (d, 1H, J = 3.2 Hz, H4), 5.42 (d, 1H, J = 8.1 Hz, H1), 4.79 (d, J = 7.6 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.68 (dd, 1H, J = 11.2, 3.4 Hz, H3), 4.52 (d, 1H, J = 7.5 Hz, O-C$\underline{H}_2$-O-Bn), 4.46 (d, 1H, J = 11.3, 8.1 Hz, H2), 4.20 (s, 2H, O-C$\underline{H}_2$-Ph/BOM), 3.89 (dd, 1H, J = 8.1, 5.2 Hz, H5), 3.20 (dd, 1H, J = 12.8, 8.4 Hz, H6), 2.96 (dd, 1H, J = 12.8, 5.1 Hz, H6), 2.23 (s, 3H, OAc), 0.71 (s, 9H, tBu), 0.13 (s, 3H, Me), 0.02 (s, 3H, Me). ^{13}C NMR ($CDCl_3$) δ 171.20, 169.01, 168.43, 137.53, 134.46, 133.12, 131.89, 129.69, 128.61, 127.84, 127.67, 127.61, 123.77, 123.42, 109.98, 94.15, 93.38, 73.70, 71.80, 70.01, 68.89, 55.09, 30.10, 28.46, 25.77, 21.342, 17.95. MS (ES, Na^+): m/z (relative intensity) 748.1 (100). HRMS (M + Na^+) calcd for $C_{36}H_{43}NO_8SeSiNa$, 748.1821; found 748.1819.

_p_-Methoxyphenyl, 4-_O_-acetyl, 3-_O_-[(benzyloxy)methyl], 2, 6-dideoxy, 6-phenylseleno-2-phthlamido-β-D-galactopyranoside (40c).

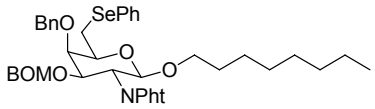


To a stirred -5 °C solution of **35c** (0.027 g, 0.040 mmol) in 0.5 mL of CH_2Cl_2 and pyridine (0.01 mL, 0.18 mmol) was added 0.07 mL of a freshly prepared solution of Tf_2O (0.01 mL, 0.08 mmol) in 0.6 mL of CH_2Cl_2. The reaction solution turned a yellow-orange color with time and the temperature was maintained between -5 °C and +10 °C. After 2 h, the reaction was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of satd. $NaHCO_3$ solution. The aqueous extract was washed with 5 mL of CH_2Cl_2 and the combined

organic extracts washed with 10 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil (0.029 g) was taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.54 (d, 2H, NPht), 7.51 (m, 2H, NPht), 7.28 (m, 2H, SePh), 7.14 (m, 3H, SePh), 6.88 (m, 2H, PMP), 6.85 (m, 2H, PMP), 5.63 (dd, 1H, J = 8.4 Hz, H1), 4.91-4.69 (m, 3H, H3/H4/H2), 4.63 (d, 2H, J = 8.3 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.19 (s, 2H, O-C$\underline{H}_2$-O-Bn), 4.02 (dd, 1H, J = 9.2, 2.3 Hz, H5), 3.74 (s, 3H, OMe), 3.36 (dd, 1H, J = 13.3, 2.5 Hz, H6), 3.15 (dd, 1H, J = 13.2, 9.2 Hz, H6). ^{19}F NMR ($CDCl_3$) δ 1.69. To the triflate glycoside was added a solution of Et_4NOAc (0.07 g, 0.269mmol) in 1 mL of DMF. After 15 min, the reaction was concentrated to remove the DMF. The crude product was dissolved in 5 mL of CH_2Cl_2 and washed twice with 5 mL of H_2O and once with satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with preparatory thin layer chromatography (hexanes:EtOAc, 2:1) to afford **40c** (0.014 g, 49%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.87 (d, 1H, J = 7.3 Hz, NPht), 7.67 (m, 1H, NPht), 7.61 (s, 2H, NPht), 7.52 (m, 2H, SePh), 7.27 (m, 3H, SePh), 7.19 (m, 3H, ArH of BOM), 6.98 (m, 2H, ArH of BOM), 6.90 (dd, 2H, J = 7.0, 2.0 Hz, PMP), 6.72 (dd, 2H, J = 7.0, 3.6 Hz, PMP), 5.86 (d, 1H, J = 8.0 Hz, H1), 5.58 (d, 1H, J = 2.9 Hz, H4), 4.77 (dd, 1H, J = 9.9, 7.6 Hz, H2), 4.72 (dd, 1H, J = 11.0, 8.0 Hz, H3), 4.50 (d, 2H, J = 7.5 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.17 (s, 2H, O-C$\underline{H}_2$-O-Bn), 3.95 (dd, 1H, J = 8.1, 5.3 Hz, H5), 3.72 (s, 3H, OMe), 3.17 (dd, 1H, J = 12.9, 4.6 Hz, H6), 3.00 (dd, 1H, J = 12.9, 5.3 Hz, H6), 2.21 (s, 3H, OAc). ^{13}C NMR ($CDCl_3$) δ 171.07, 168.94, 168.12, 155.85, 151.26, 137.41, 134.56, 133.53, 131.77, 129.86, 129.75, 128.64, 127.92, 127.59, 123.99, 123.69, 118.98, 114.80, 98.28, 93.39, 73.98, 71.97, 70.07, 68.64, 56.00, 52.85, 28.36, 21.35. MS (ES, Na^+): m/z

(relative intensity) 740.13 (100). HRMS (M + Na^+) calcd for $C_{37}H_{35}NO_9SeNa$, 740.1375; found 740.1378.

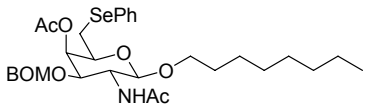
Octyl 4-*O*-benzyl-3-O-[(benzyloxy)methyl]- 2, 6-dideoxy-6-phenylseleno-2-phthalamido- Ξ-D-galactopyranoside (41).



To a stirred solution of **40a** (1.25 g, 1.73 mmol) in 50 mL of THF:MeOH (1:1) was added 0.5M NaOMe solution (0.03mL, 0.553 mmol). After 21 h, the reaction solution was quenched with 2.00 g of Dowex 50W H^+ form resin (2.1 meq/mL) and gently stirred for 15 min. The suspension was filtered and the filtrate concentrated. The resulting oil was purified using flash column chromatography (hexanes:EtOAc, 3:1) to afford the free C-4 OH glycoside (1.11 g, 95%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.81 (m, 1H, Pht), 7.66 (m, 3H, Pht), 7.55 (m, 2H, ArH of BOM), 7.27 (m, 3H, ArH of BOM), 7.23 (m, 5H, PhSe), 7.21 (m, 3H, Bn), 7.08 (m, 2H, Bn), 5.10 (d, 1H, J = 8.0 Hz, H1), 4.77 (d, 1H, J = 7.3 Hz, -O-C$\underline{H}_2$-O-Bn), 4.65 (d, 1H, J = 11.8 Hz, C$\underline{H}_2$-Ph), 4.53 (m, 1H, Hz, H3), 4.39-31 (m, 2H, -O-C$\underline{H}_2$-Ph), 4.27 (m, 1H, H2), 3.82-3.73 (m, 3H, C$\underline{H}_2$-octyl/H4/H5), 3.40-3.31 (m, 2H, C$\underline{H}_2$-octyl, H6), 3.23 (m, 1H, H6), 2.49 (d, 1H, J = 2.9 Hz, -O$\underline{H}$), 1.39-1.32 (bs, 2H, C$\underline{H}_2$-octyl), 1.18-0.95 (bs, 10H, C$\underline{H}_2$-octyl), 0.82 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.92, 168.58, 167.65, 136.81, 133.84, 133.79, 132.29, 131.39, 129.87, 128.99, 128.14, 127.43, 127.21, 126.83, 123.28, 122.85, 98.24, 93.69, 75.00, 74.13, 69.67, 69.27, 67.60, 60.18, 51.94, 31.45, 29.05, 28.92, 27.44, 25.62, 22.39, 20.83, 14.01, 13.87, -0.843. MS (ES, Na^+): m/z (relative intensity) calcd for

$C_{35}H_{43}NO_7SeNa$, 706.2; found 706.2 (100). To a stirred 0 °C solution of the C-4 OH glycoside (0.22 g, 0.322 mmol) in 10mL of THF was added NaH (80% in oil, 0.015 g, 0.645 mmol). The resulting mixture was stirred for 30 min and had BnBr (0.08 mL, 0.645 mmol) and NBu_4I (0.60 g, 1.610 mmol) added to it. After 20.5 h, the reaction mixture was diluted with 50 mL of EtOAc and washed with 50 mL of H_2O, satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil was purified using flash column chromatography (hexanes:EtOAc, 5:1) to afford **41** (0.23 g, 92%; 87%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.64 (m, 1H, Pht), 7.47 (m, 3H, Pht), 7.37 (m, 2H, ArH of BOM), 7.34 (m, 3H, ArH of BOM), 7.29 (m, 5H, PhSe), 7.22 (m, 3H, Bn), 7.04 (m, 2H, Bn/Ph), 5.12 (d, 1H, J = 8.4 Hz, H1), 5.00 (d, 1H, J = 11.5 Hz, -O-C$\underline{H}_2$-O-Bn), 4.75 (d, 1H, J = 6.9 Hz, C$\underline{H}_2$-Ph), 4.72 (dd, 1H, J = 10.3, 2.6 Hz, H3), 4.62 (m, 1H, C$\underline{H}_2$-Ph), 4.58 (dd, 1H, J = 11.2, 8.4 Hz, H2), 4.55 (d, 1H, J = 11.6 Hz, -O-C$\underline{H}_2$-Ph), 4.28 (d, 2H, J = 12.1, 6.1 Hz, -O-C$\underline{H}_2$-Ph), 4.10 (d, 1H, J = 2.4 Hz, H4), 3.77 (m, 1H, C$\underline{H}_2$-octyl), 3.67 (m, 1H, C$\underline{H}_2$-octyl), 3.35 (m, 1H, H5), 3.23 (dd, 1H, J = 12.6, 6.3 Hz, H6), 3.02 (dd, 1H, J = 12.6, 7.6 Hz, H6), 1.25-1.16 (bs, 2H, C$\underline{H}_2$-octyl), 1.12-0.97 (bs, 10H, C$\underline{H}_2$-octyl), 0.81 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 168.86, 167.76, 138.26, 137.14, 133.08, 132.51, 131.67, 129.97, 128.16, 128.26, 128.24, 128.22, 127.61, 127.46, 127.17, 127.04, 123.35, 122.87, 98.50, 93.94, 76.36, 74.72, 73.59, 74.35, 69.73, 69.40, 52.69, 31.59, 29.20, 29.07, 29.03, 27.98, 25.76, 22.52. MS (ES, Na^+): m/z (relative intensity) 794.2 (100). HRMS (M + Na^+) calcd for $C_{43}H_{47}NO_7SeNa$, 794.2572; found 794.2604.

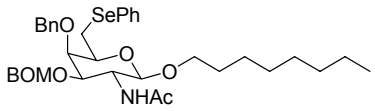
Octyl 2-acetamido-4-*O*-acetyl-3-*O*-[(benzyloxy)methyl]-2, 6-dideoxy-6-phenylseleno-∃-D-galactopyranoside (42a).



To a stirred solution of **40a** (0.150 g, 0.207 mmol) in 10 mL of EtOH in a Schlenk tube was added $H_2NNH_2 \cdot H_2O$ (1.00 mL, 19.7 mmol). The reaction was placed under a gentle vacuum, the tube sealed and heated to 100 °C. After 43 h, the reaction was cooled, the tube opened and the reaction mixture concentrated. The resulting oil/solid was dissolved in 20 mL of EtOAc and washed with 20 mL of satd. $NaHCO_3$ solution. The aqueous extract was washed with 20 mL of EtOAc and the combined organic extracts washed with 50 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting colorless oil (0.110 g) was taken on without any purification. The resulting oil (0.110 g, 0.200 mmol) was dissolved in 3 mL of pyridine and 3 mL of Ac_2O. After 25.5 h, the reaction was diluted with 40 mL of EtOAc and washed with 40 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using flash column chromatography (hexanes:EtOAc, 1:1) to afford **42a** (0.100 g, 76%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.51 (m, 3H, ArH of BOM), 7.49 (m, 2H, ArH of BOM), 7.33 (m, 5H, PhSe), 5.61 (d, 1H, J = 7.5 Hz, N-H), 5.49 (d, 1H, J = 3.1 Hz, H4), 4.93 (d, 1H, J = 8.4 Hz, H1), 4.83 (d, 1H, J = 7.2 Hz, -O-CH_2-O-Bn), 4.67 (m, 1H, -O-CH_2-OBn), 4.57-4.54 (d, 2H, -O-CH_2-Ph),4.50 (dd, 1H, J = 10.8, 3.2 Hz, H3), 3.87 (dd, 1H, J = 9.5, 6.5 Hz, H2), 3.74 (m, 2H, CH_2, octyl), 3.45 (m, 1H, H5), 3.11 (dd, 1H, J = 12.8, 7.9 Hz, H6), 2.89 (dd, 1H, J = 12.8, 5.7 Hz, H6), 2.05 (s, 3H, NHAc), 1.89

(s, 3H, OAc), 1.25 (bs, 12H, CH_2-octyl), 0.88 (bs, 3H, CH_3). ^{13}C NMR ($CDCl_3$) δ 170.46, 170.38, 137.37, 132.86, 129.61, 129.14, 128.37, 127.69, 127.60, 127.42, 127.22, 99.67, 93.04, 73.00, 72.35, 69.99, 69.66, 68.67, 54.45, 31.72, 29.36, 29.24, 29.18, 27.85, 25.82, 23.44, 22.55, 20.78, 13.99. MS (ES, Na^+): m/z (relative intensity) 658.2 (100). HRMS ($M + Na^+$) calcd for $C_{32}H_{45}NO_7SeNa$, 658.2259; found 658.2266.

Octyl 2-acetamido-4-*O*-benzyl-3-*O*-[(benzyloxy)methyl]- 2, 6-dideoxy-6-phenylseleno-∃-D-galactopyranoside (42b).

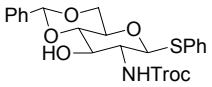


To a stirred solution of **41** (0.080 g, 0.103 mmol) in 4mL of EtOH in a Schlenk tube was added $H_2NNH_2 \cdot H_2O$ (0.45 mL, 9.323 mmol). The reaction placed under a gentle vacuum, the tube sealed and heated to 100 °C. After 44 h, the reaction was cooled, the tube opened and the reaction mixture concentrated. The resulting oil/solid was dissolved in 30 mL of EtOAc and washed with 15 mL of satd. $NaHCO_3$ solution. The aqueous extract was washed with 25 mL of EtOAc and the combined organic extracts washed with 40 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil was purified using a short silica gel plug (hexanes:EtOAc, 1:1) to afford the free amine (0.060 g) as a colorless oil: ^1H NMR ($CDCl_3$) δ 7.45 (m, 2H, ArH of BOM), 7.36 (m, 3H, ArH of BOM), 7.30 (m, 5H, PhSe), 7.25 (m, 5H, Bn), 4.90 (d, 1H, J = 6.6 Hz, C$\underline{H_2}$-Ph,), 4.88 (d, 1H, J = 11.0 Hz, -O-C$\underline{H_2}$-O-Bn), 4.81 (d, 1H, J = 6.8 Hz, O-C$\underline{H_2}$-Ph), 4.72 (m, 1H, -O-C$\underline{H_2}$-OBn), 4.63 (d, 1H, J = 11.8 Hz, -O-C$\underline{H_2}$-Ph), 4.53 (d, 1H, J = 11.6 Hz, -O-C$\underline{H_2}$-Ph), 4.09 (d, 1H, J = 7.8 Hz, H1),

3.92 (d, 1H, J = 2.3 Hz, H4), 3.87 (m, 1H, C$\underline{H}_2$-octyl), 3.54 (dd, 1H, J = 10.3, 2.6 Hz, H3), 3.47 (m, 1H, H5), 3.87 (m, 1H, C$\underline{H}_2$-octyl), 3.27 (dd, 1H, J = 10.2, 7.7 Hz, H2), 3.20 (dd, 1H, J = 12.5, 6.6 Hz, H6), 2. 97 (dd, 1H, J = 12.5, 7.3 Hz, H6), 1.60 (bs, 2H, C$\underline{H}_2$-octyl), 1.25 (bs, 10H, C$\underline{H}_2$- octyl), 0.85 (s, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 138.36, 137.38, 132.59, 130.01, 129.11, 128.49, 128.22, 128.12, 127.85, 127.80, 127.58, 127.00, 104.49, 93.96, 81.45, 74.55, 73.76, 70.08, 69.89, 52.51, 31.78, 29.53, 29.36, 29.18, 28.19, 25.99, 22.61. The amine (0.060 g, 0.093 mmol) was immediately dissolved in 3 mL of Ac_2O and 3 mL of pyridine and had 10 mg of DMAP added to it. After 47 h, the reaction was diluted to 40 mL of EtOAc and washed with 40 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil was purified using flash column chromatography (hexanes:EtOAc, 1:1) to afford **42b** (0.043 g, 61%, 2 steps): ^{1}H NMR ($CDCl_3$) δ 7.43 (m, 2H, ArH of BOM), 7.33 (m, 3H, ArH of BOM), 7.29 (m, 5H, PhSe), 7.25 (m, 5H, Bn), 5.87 (d, 1H, J = 6.9 Hz, N$\underline{H}$), 4.92 (d, 1H, J = 3.6 Hz, H4), 4.91 (d, 1H, J = 7.7 Hz, H1), 4.86 (d, 1H, J = 6.3 Hz, C$\underline{H}_2$-Ph,), 4.76 (d, 1H, J = 6.5 Hz, -O-C$\underline{H}_2$-Ph), 4.66 (d, 2H, -O-C$\underline{H}_2$-OBn), 4.11 (dd, 1H, J = 7.0, 4.0 Hz, H3), 4.00 (d, 1H, -O-C$\underline{H}_2$-Ph), 4.48 (d, 1H, J = 10.7 Hz, -O-C$\underline{H}_2$-Ph), 3.82 (m, 1H, C$\underline{H}_2$, octyl), 3.57-3.53 (dd, 2H, J = 12.6, 7.6 Hz, H5/H2), 3.43 (m, 1H, C$\underline{H}_2$, octyl), 3.19 (dd, 1H, J = 12.4 Hz, H6), 2. 93 (dd, 1H, J = 12.4, 7.6 Hz, H6), 1.90 (s, 3H, NHAc), 1.54 (bs, 2H, C$\underline{H}_2$-octyl), 1.25 (bs, 10H, C$\underline{H}_2$-octyl), 0.86 (s, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.65, 138.22, 137.44, 132.44, 129.89, 129.07, 128.42, 128.28, 128.18, 128.09, 127.89, 127.72, 127.56, 127.49, 126.95, 99.35, 94.22, 76.45, 74.86, 74.62, 74.17, 69.82, 69.61, 60.29, 54.73, 31.72, 29.37, 29.25, 29.19, 27.99, 25.82, 23.50, 22.55, 20.94, 14.09, 14.00. MS (ES, Na^+): m/z

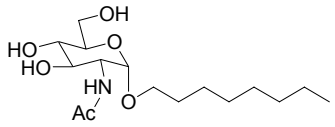
(relative intensity) 706.3 (100). HRMS (M + Na^+) calcd for $C_{37}H_{49}NO_6SeNa$, 706.2623; found 706.2628.

Phenylthio 4, 6-*O*-benzylidene-2-deoxy-2-(2, 2, 2-trichloroethoxycarbonyl) amido-∃-D-glucopyranoside (45).



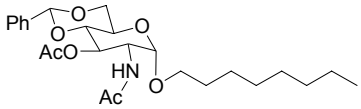
To a stirred 0 °C solution of **44** (3.55 g, 6.20 mmol) in 100 mL of MeOH and was added NaOMe powder (0.33 g, 6.197 mmol). After 2 h, 1.8 g of Dowex 50W H^+ form resin (2.1 meq/mL) was added and the reaction mixture was gently stirred for 20 min. The reaction mixture was filtered and the filtrate concentrated. To a suspension of the resulting triol in 75 mL of dry CH_3CN was added $PhCH(OMe)_2$ (1.58 mL, 10.5 mmol) and pTsOH (0.29 g, 1.55 mmol). After 20 h, the reaction was placed under a gentle vacuum. After 1 h, the reaction had 1 g of K_2CO_3 added to it and was stirred for 30 min. The mixture was filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (EtOAc) to afford compound **45** (3.00 g, 90%, 2 steps) as a colorless oil/solid: ^1H NMR ($CDCl_3$) δ 7.45 (m, 5H, Ph), 7.35 (m, 5H, Ph), 5.54 (s, 1H, benzylidene), 5.25 (d, 1H, H1), 4.83 (d, 1H, J = 7.2, C$\underline{H}_2$-Troc), 4.83 (d, 1H, J = 7.2, C$\underline{H}_2$-Troc), 4.70 (m, 1H, C$\underline{H}_2$-Troc), 4.36 (m, 1H, H3), 3.76 (m, 1H, H4), 3.54-3.45 (m, 4H, H2/H5/H6/H6). MS (ES, Na^+): m/z (relative intensity) calcd for $C_{22}H_{23}NO_6SCl_3Na$, 566.0; found 566.0 (100).

Octyl 2-acetamido-2-deoxy-α-D-glucopyranoside (49).



To a stirred 0 °C suspension of *N*-acetyl D-glucosamine, **48**, (2.00 g, 9.04 mmol) in 1-octanol (14 mL, 90.04 mmol) was added $BF_3 \cdot OEt_2$ (1.14 mL, 9.04 mmol). The reaction mixture was heated to 70 °C. After 3.5 h, the reaction was concentrated and the desired product crystallized with EtOH and ether to afford **49** (0.700 g, 23%) as a white powder: mp 103-106 °C. ^{1}H NMR ($CDCl_3$) δ 4.78 (d, 1H, J = 3.5 Hz, H1), 4.38 (d, 1H, J = 8.3 Hz, N-H), 3.86 (dd, 1H, J = 10.6, 3.6 Hz, H2), 3.79 (dd, J = 9.7 Hz, H3), 3.71-3.65 (m, 3H, H4/H6/H6), 3.56 (m, 1H, H5), 3.53 (m, 1H, CH_2-octyl), 3.34 (m, 1H, CH_2-octyl), 1.97 (s, 3H, NHAc), 1.57 (bs, 2H, CH_2-octyl), 1.30-1.19 (bs, 10H, CH_2-octyl), 0.88 (t, 3H, CH_3-octyl). ^{13}C NMR ($CDCl_3$) δ 96.88, 72.22, 71.24, 70.86, 67.40, 61.50, 61.20, 54.05, 32.14, 31.52, 29.04, 28.95, 25.79, 25.44, 22.22, 21.04, 12.91. MS (ES, Na^+): m/z (relative intensity) 356.2 (100). HRMS (M + Na^+) calcd for $C_{16}H_{31}NO_6Na$, 356.2049; found 356.2058.

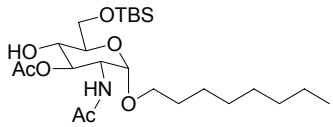
Octyl 2-acetamido-3-*O*-acetyl-4, 6-*O*-benzylidene-2-deoxy-α-D-glucopyranoside (50).



To a stirred solution of **49** (0.50 g, 1.50 mmol) in 5 mL of DMF were added $PhCH(OMe)_2$ (0.31 mL, 2.099 mmol) and $pTsOH \cdot H_2O$ (0.028 mg, 0.150 mmol). After 19 h, the reaction was concentrated to remove the DMF. The crude product was crystallized by adding 50 mL of CH_2Cl_2:MeOH (6:1) and approximately 2 mL of H_2O. The product was precipitated by slowly adding hexanes to the solution to afford the

benzylidene (0.60 g, 95 %) as a white powder: ^{1}H NMR ($CDCl_3$) δ 7.49 (bs, 2H, Ph), 7.35 (bs, 3H, Ph), 5.83 (d, 1H, J = 7.5 Hz, N-H), 5.56 (s, 1H, benzylidene), 4.81 (d, 1H, J = 3.5 Hz, H1), 4.27-4.20 (m, 2H, H3/H2), 3.89 (d, 1H, H4), 3.78 (d, 2H, H6/H6), 3.58 (dd, 1H, H5), 3.48 (m, 1H, CH_2-octyl), 3.39 (m, 1H, CH_2-octyl), 2.06 (s, 3H, NHAc), 1.58-1.55 (bs, 2H, CH_2-octyl), 1.28 (bs, 10H, CH_2-octyl), 0.88 (s, 3H, CH_3-octyl). ^{13}C NMR ($CDCl_3$) δ 134.46, 129.74, 129.19, 128.28, 126.29, 101.89, 97.64, 82.12, 70.79, 68.85, 68.28, 62.42, 54.12, 31.80, 29.35, 29.25, 26.17, 22.64, 14.08, 0.01. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{37}H_{35}NO_9SeNa$, 444.2; found 444.2 (100). The resulting benzylidene (0.60 g, 1.423 mmol) was dissolved in pyridine (2.30 mL, 28.5 mmol) and Ac_2O (2.68 mL, 28.467 mmol). After 19 h, the reaction was diluted with 25 mL of EtOAc and washed with 25 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (hexanes:EtOAc, 1:2) to afford **50** (0.44 g, 68%; 65%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.41 (bs, 2H, Ph), 7.31 (bs, 3H, Ph), 5.86 (d, 1H, J = 9.5 Hz, N-H), 5.49 (s, 1H, benzylidene), 5.27 (d, 1H, J = 10.2 Hz, H3), 4.78 (d, 1H, J = 3.6 Hz, H1), 4.28 (dd, 1H, J = 9.8, 3.8 Hz, H2), 4.24 (d, 1H, J = 10.3, 4.8 Hz, H6), 3.76 (d, 1H, J = 10.3, 6.2 Hz, H6), 3.74 (m, 1H, H4), 3.68-3.63 (dd, 2H, H5/CH_2-octyl), 3.36 (m, 1H, CH_2-octyl), 2.04 (s, 3H, OAc), 1.93 (s, 3H, NHAc), 1.58-1.55 (bs, 2H, CH_2-octyl), 1.28-1.21 (bs, 10H, CH_2-octyl), 0.85 (s, 3H, CH_3-octyl). ^{13}C NMR ($CDCl_3$) δ 171.29, 169.96, 136.92, 128.95, 128.08, 126.04, 101.39, 97.72, 78.93, 70.30, 68.77, 68.31, 62.68, 60.25, 52.49, 31.68, 29.31, 29.19, 26.14, 26.00, 23.04, 22.51, 20.89, 20.78, 14.05, 13.95. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{25}H_{37}NO_7Na$, 486.3; found 486.3 (100).

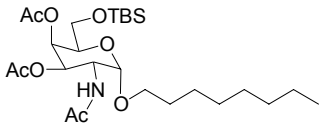
Octyl 2-acetamido-3-*O*-acetyl-6-*O*-*t*-butyldimethylsilyl-2-deoxy-α-D-glucopyranoside (51).



A solution of **50** (0.44 g, 0.95 mmol) in 15 mL of H_2O and AcOH (1:1) was heated to reflux. After 2 h, the reaction was cooled and concentrated. The crude product was diluted with 30 mL of EtOAc and washed with 20 mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (EtOAc) to afford the diol (0.24 g, 73 %) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 5.96 (d, 1H, J = 9.2 Hz, N-H), 4.97 (d, 1H, J = 9.7 Hz, H3), 4.68 (d, 1H, H1), 4.08 (dd, 1H, J = 8.5 Hz, H2), 3.71 (d, 2H, H6/H6), 3.71 (d, 1H, H4), 3.55 (d, 1H, -OH), 3.45 (dd, 1H, H5), 3.32-3.26 (dd, 2H, CH_2-octyl), 1.98 (s, 3H, NHAc), 1.82 (s, 3H, OAc), 1.47-1.42 (bs, 2H, CH_2-octyl), 1.13 (bs, 10H, CH_2-octyl), 0.77 (s, 3H, CH_3-octyl). To a stirred solution of the diol in 5 mL of DMF were added imidazole (0.13g, 1.917 mmol) and TBS-Cl (0.12g, 0.799 mmol). After 18 h, the reaction was concentrated to remove the DMF. The crude product was dissolved in 20 mL of EtOAc and washed with 10 mL of H_2O and satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (EtOAc) to afford **51** (0.14 g, 45%; 32%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 5.73 (d, 1H, J = 9.5 Hz, N-H), 5.08 (d, 1H, J = 10.6, 9.1 Hz, H3), 4.72 (d, 1H, J = 3.6 Hz, H1), 4.16 (dd, 1H, J = 9.8, 3.6 Hz, H2), 3.87 (d, 1H, J = 10.5, 4.6 Hz, H6), 3.79 (d, 1H, J

= 10.5, 5.5 Hz, H6), 3.71 (d, 1H, J = 9.3, 2.7 Hz, H4), 3.66-3.61 (dd, 2H, H5/C$\underline{H}_2$-octyl), 3.37-3.33 (dd, 1H, C$\underline{H}_2$-octyl), 3.28 (d, 1H, J = 2.7 Hz, -OH), 2.01 (s, 3H, NHAc), 1.91 (s, 3H, OAc), 1.57-1.53 (bs, 2H, C$\underline{H}_2$-octyl), 1.28-1.21 (bs, 10, C$\underline{H}_2$-octyl), 0.86 (s, 12H, tBu, C$\underline{H}_3$-octyl), 0.10 (s, 6H, Me). ^{13}C NMR ($CDCl_3$) δ 172.03, 169.94, 96.99, 73.98, 71.03, 70.31, 68.02, 64.37, 60.32, 51.73, 31.73, 29.27, 29.19, 26.11, 25.78, 23.16, 22.56, 20.96, 18.19, 14.11, 14.10, -5.54, -5.58. MS (ES, Na^+): m/z (relative intensity) 512.4 (100). HRMS (M + Na^+) calcd for $C_{24}H_{47}NO_7SeSiNa$, 512.3020; found 512.3025.

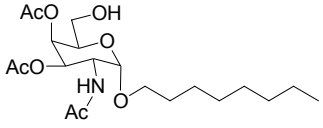
Octyl 2-acetamido-3, 4-di-*O*-acetyl-6-*O*-*t*-butyldimethylsilyl-2-deoxy-α-D-galactopyranoside (52).



To a stirred -5 °C solution of **51** (0.140 g, 0.285 mmol) in 5 mL of CH_2Cl_2 and pyridine (0.10 mL, 1.28 mmol) was added a freshly prepared solution of Tf_2O (0.09 mL, 0.571 mmol) in 0.85 of mL CH_2Cl_2. The reaction solution turned a yellow-orange color with time and the temperature was maintained between -5 °C and +10 °C. After 2.5 h, the reaction was warmed to room temperature and diluted to 10 mL of CH_2Cl_2 and washed with 10 mL of satd. Cu_2SO_4, H_2O, satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil (0.156 g) was taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 5.71 (d, 1H, 9.5 Hz, N-$\underline{H}$), 5.34 (d, 1H, J = 9.9 Hz, H4), 4.77 (d, 1H, J = 3.6 Hz, H1), 4.24 (dd, 1H, J = 10.1, 3.6 Hz, H2), 3.85-3.80 (m, 2H, H3/H5), 3.79 (d, 2H, J = 2.5 Hz, H6/H6), 3.65 (m, 1H, C$\underline{H}_2$-octyl), 3.39 (m, 1H, C$\underline{H}_2$-octyl), 2.09 (s, 3H, NHAc), 1.86 (s, 3H, OAc), 1.57-1.55 (bs, 2H, C$\underline{H}_2$-

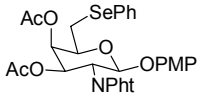
octyl), 1.27-1.25 (bs, 10H, C$\underline{H}_2$-octyl), 0.87 (s, 12H, tBu, C$\underline{H}_3$-octyl), 0.06 (s, 6H, Me). ^{13}C NMR ($CDCl_3$) δ 171.16, 169.86, 96.72, 79.05, 70.59, 69.22, 68.50, 60.77, 52.48, 31.72, 29.23, 29.16, 26.04, 25.65, 23.09, 22.56, 20.55, 18.21, 13.99, -5.51, -5.67. ^{19}F NMR ($CDCl_3$) δ 1.58. To the crude triflate glycoside was added a solution of Et_4NOAc (0.33 g, 1.25 mmol) in 5 mL of DMF. After 40 min, the reaction was concentrated and the crude red oil dissolved in 50 mL of EtOAc and washed twice with 25 mL of H_2O and once with satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (hexanes:EtOAc, 2:1) to afford **52** (0.050 g, 35%, 2 steps) as an oil: ^{1}H NMR ($CDCl_3$) δ 5.59 (d, 1H, J = 10.0 Hz, N-$\underline{H}$), 5.39 (d, 1H, J = 2.9 Hz, H4), 5.14 (dd, 1H, J = 14.4, 3.2 Hz, H3), 4.80 (d, 1H, J = 3.7 Hz, H1), 4.52 (dd, 1H, J = 8.5, 3.6 Hz, H2), 3.94 (dd, 1H, J = 12.9, 6.6 Hz, H5), 3.68 (m, 1H, C$\underline{H}_2$-octyl), 3.59-3.53 (dd, 2H, J = 10.1, 2.9 Hz, H6), 3.36 (m, 1H, C$\underline{H}_2$-octyl), 2.12 (s, 3H, NHAc), 2.02 (s, 3H, OAc), 1.95 (s, 3H, OAc), 1.56-1.55 (bs, 2H, C$\underline{H}_2$-octyl), 1.26-1.19 (bs, 10H, C$\underline{H}_2$-octyl), 0.87 (s, 12H, tBu, C$\underline{H}_3$-octyl), 0.01 (s, 6H, Me). ^{13}C NMR ($CDCl_3$) δ 171.06, 170.96, 170.12, 169.84, 97.39, 69.33, 68.92, 68.15, 67.39, 61.12, 60.31, 48.01, 31.73, 29.27, 29.20, 26.14, 25.67, 23.28, 22.57, 20.97, 20.75, 18.06, 14.12, 14.10, -5.64, -5.71. MS (ES, Na^+): m/z (relative intensity) 554.4 (100). MS (ES, Na^+): m/z (relative intensity) 554.3 (100). HRMS (M + Na^+) calcd for $C_{26}H_{46}NO_8SiNa$, 554.3125; found 554.3128.

Octyl 2-acetamido-3, 4-di-*O*-acetyl-2-deoxy-α-D-galactopyranoside (53).



To a stirred 0 °C solution of **52** (0.050 g, 0.094 mmol) in 3 mL of CH_3CN and pyridine (0.25 mL, 3.10 mmol) in a Nalgene bottle was added 0.25 mL of HF·pyridine. The reaction was allowed to warm to room temperature. After 3.5 h, the reaction was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified by preparatory thin layer chromatography (hexanes:EtOAc, 1:1) to afford **53** (0.03 g, 77%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 5.65 (d, 1H, N-H), 5.30 (d, 1H, J = 2.8 Hz, H4), 5.16 (dd, 1H, J = 11.2, 3.1 Hz, H3), 4.82 (d, 1H, J = 3.6 Hz, H1), 4.53 (dd, 1H, J = 10.0, 3.6 Hz, H2), 3.97 (dd, 1H, J = 6.3 Hz, H5), 3.72-3.60 (m, 2H, H6/CH$_2$-octyl), 3.45 (m, 1H, H6), 3.36 (m, 1H, CH$_2$-octyl), 2.08 (s, 3H, NHAc), 2.02 (s, 3H, OAc), 1.93 (s, 3H, OAc), 1.52 (bs, 2H, CH$_2$-octyl), 1.26 (bs, 10H, CH$_2$-octyl), 0.85 (s, 3H, CH$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 97.56, 71.12, 68.46, 68.34, 67.86, 67.51, 63.09, 47.65, 31.82, 29.71, 29.34, 29.28, 26.24, 23.36, 22.65, 21.01, 20.84, 14.10, 0.00. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{20}H_{35}NO_8SeNa$, 440.2; found 440.2 (100).

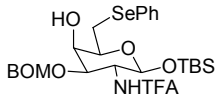
***p*-Methoxyphenyl, 3, 4-di-*O*-acetyl, 3-*O*-[(benzyloxy)methyl], 2, 6-dideoxy, 6-phenylseleno-2-phthlamido-β-D-galactopyranoside (58).**



To a stirred 0 °C solution of **40c** (0.150 g, 0.209 mmol) in 2 mL of CH_2Cl_2 were added AcBr (0.006 mL, 0.413 mmol) and $BF_3{\cdot}OEt_2$ (0.0015 mL, 0.0209 mmol). After 20 min, the reaction was warmed to room temperature. After 5 h, the reaction was diluted to 5 mL of CH_2Cl_2 and washed three times with 5 mL of H_2O and once with satd. NaCl

solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified by flash column chromatography (hexanes:EtOAc, 2.5:1) to afford **58** (0.106 g, 80%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.82 (d, 2H, NPht), 7.75 (m, 2H, NPht), 7.53 (m, 2H, SePh), 7.29 (m, 3H, SePh), 6.92 (m, 2H, PMP), 6.75 (m, 2H, PMP), 5.86 (dd, 1H, J = 11.4, 3.3 Hz, H3), 5.77 (d, 1H, J = 8.5 Hz, H1), 5.60 (d, 1H, J = 5.3 Hz, H4), 4.81 (dd, 1H, J = 11.5, 8.5 Hz, H2), 4.03 (dd, 1H, J = 8.0, 6.0 Hz, H5), 3.74 (s, 3H, OMe), 3.19 (dd, 1H, J = 12.9, 8.3 Hz, H6), 3.00 (dd, 1H, J = 12.9, 7.5 Hz, H6), 2.22 (s, 3H, OAc), 1.89 (s, 3H, OAc). MS (ES, Na^+): m/z (relative intensity) 662.0 (100). HRMS (M + Na^+) calcd for $C_{31}H_{29}NO_9SeNa$, 662.0905; found 662.0901.

_t_-Butyldimethylsilyl, 4-_O_-acetyl, 3-_O_-[(benzyloxy)methyl], 2, 6-dideoxy-6-phenylseleno-2-trifluoroacetamido-β-D-galactopyranoside (60).

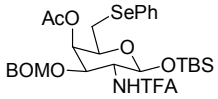


To a suspension of **40b** (0.125 g, 0.170 mmol) in 25 mL of EtOH in a Schlenk tube was added $H_2NNH_2 \cdot H_2O$ (0.79 mL, 16.2 mmol). The reaction was placed under a gentle vacuum, the tube sealed and heated to 100 °C. After 68 h, the reaction was cooled, the tube opened and the reaction mixture concentrated. The resulting oil/solid was dissolved in 100 mL of EtOAc and washed with 75 mL of satd. $NaHCO_3$ solution. The aqueous extract was washed with 75 mL of EtOAc and the combined organic extracts washed with 150 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil was purified using a short silica gel plug (hexanes:EtOAc, 1:1) to afford the free amino alcohol (0.080g, 85%) as a colorless oil:

^{1}H NMR ($CDCl_3$) δ 7.48 (m, 2H, SePh), 7.33 (m, 5H, ArH of BOM), 7.24 (m, 3H, SePh), 4.93 (d, 1H, J = 7.0 Hz, O-C$\underline{H}_2$-O-Bn), 4.86 (d, 1H, J = 7.0 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.69 (s, 1H, J = 11.7 Hz, O-C$\underline{H}_2$-Ph/BOM), 4.65 (s, 1H, J = 11.7 Hz, O-C$\underline{H}_2$-Ph/BOM), 4.37 (d, 1H, J = 7.6 Hz, H1), 4.03 (d, 1H, J = 2.9 Hz, H4), 3.55 (dd, 1H, J = 6.8 Hz, H5), 3.45 (dd, 1H, J = 10.1, 3.1 Hz, H3), 3.28 (dd, 1H, J = 12.7, 7.3 Hz, H6), 3.14 (dd, 1H, J = 12.7, 6.4 Hz, H6), 3.02 (dd, 1H, J = 10.1, 7.7 Hz, H2), 0.92 (s, 9H, tBu), 0.17 (s, 3H, Me), 0.01 (s, 3H, Me). ^{13}C NMR ($CDCl_3$) δ 207.32, 137.51, 132.62, 132.27, 130.53, 129.48, 128.90, 128.31, 127.26, 99.56, 94.78, 81.59, 76.93, 74.61, 70.57, 67.93, 54.33, 31.27, 28.14, 26.13, 18.34, -3.48, -4.95. MS (ES, Na^+): m/z (relative intensity) 576.1 (100). HRMS ($M + Na^+$) calcd for $C_{26}H_{40}NO_5SeSiNa$, 576.1660; found 576.1653. To a stirred 0 °C solution of the free amino alcohol in pyridine (0.50 mL, 6.46 mmol) was added TFAA (0.09 mL, 0.63 mmol). After 45 min, the solution was diluted with 25 mL of CH_2Cl_2 and washed with 25 mL of satd. $CuSO_4$, H_2O, satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil was dissolved in 5 mL of EtOH, 10 mL of H_2O and 1 mL of satd. $NaHCO_3$ solution. After 4 h, the solution was neutralized with AcOH to pH = 6 and concentrated to leave the H_2O. The aqueous extract was washed with 10 mL of EtOAc two times and the combined organic extracts were washed with 20 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated to afford **60** (0.078 g, 95%; 80%, 2 steps) and taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.49 (m, 2H, SePh), 7.30 (m, 3H, SePh), 7.25 (m, 5H, ArH of BOM), 6.67 (d, 1H J = 8.1 Hz, N-$\underline{H}$), 4.88 (d, 1H, J = 7.9 Hz, H1), 4.81 (d, 1H, J = 7.0 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.72 (d, 1H, J = 7.0 Hz, O-C$\underline{H}_2$-Ph/Bn), 4.57 (m, 2H, O-C$\underline{H}_2$-O-Bn), 4.08-4.04 (m, 2H, H5/H4), 3.83 (dd, 1H, J = 9.9 Hz, H2), 3.60 (d, 1H, J =

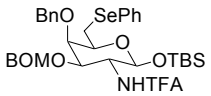
6.8 Hz, H3), 3.27 (dd, 1H, J = 12.7, 7.2 Hz, H6), 3.13 (dd, 1H, J = 12.7, 6.5 Hz, H6), 0.86 (s, 9H, tBu), 0.13 (s, 3H, Me), 0.07 (s, 3H, Me). ^{19}F NMR ($CDCl_3$) δ 0.23.

_t_-Butyldimethylsilyl, 4-_O_-acetyl, 3-_O_-[(benzyloxy)methyl], 2, 6-dideoxy-6-phenylseleno-2-trifluoroacetamido-β-D-galactopyranoside (61a).



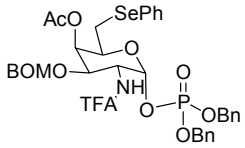
Compound **60** (0.077 g, 0.118 mmol) was dissolved in pyridine (0.60 mL, 7.42 mmol) and Ac_2O (0.6 mL, 6.36 mmol). After 15 h, the reaction was diluted to 25 mL of EtOAc and washed with 25 mL of satd. $CuSO_4$, H_2O, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using flash column chromatography to afford **61a** (0.076 g, 92%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.47 (m, 2H, SePh), 7.33 (m, 3H, SePh), 7.27 (m, 5H, ArH of BOM), 6.39 (d, J = 8.3 Hz, N-H), 5.44 (d, 1H, J = 2.9 Hz, H4), 4.90 (d, 1H, J = 7.9 Hz, H1), 4.79 (d, 2H, J = 7.4 Hz, O-CH_2-Ph/Bn), 4.57 (m, 2H, O-CH_2-O-Bn), 4.49 (s, 2H, J = 12.1 Hz, O-CH_2-Ph/BOM), 4.15 (dd, 1H, J = 11.1, 3.2 Hz, H3), 3.85 (d, 1H, H2), 3.68 (m, 1H, H5), 3.10 (dd, 1H, J = 12.8, 8.3 Hz, H6), 2.86 (dd, 1H, J = 12.8, 5.2 Hz, H6), 2.14 (s, 3H, OAc), 0.87 (s, 9H, tBu), 0.15 (s, 3H, Me), 0.07 (s, 3H, Me). ^{13}C NMR ($CDCl_3$) δ 170.97, 157.85, 157.56, 137.47, 133.13, 130.12, 129.73, 128.93, 128.35, 128.15, 127.77, 117.24, 95.67, 92.96, 73.61, 72.74, 70.30, 68.32, 55.92, 30.12, 28.19, 25.93, 21.27, 18.22, 1.44, -3.55, -5.08. ^{19}F NMR ($CDCl_3$) δ 0.34. MS (ES, Na^+): m/z (relative intensity) 714.1 (100). HRMS (M + Na^+) calcd for $C_{30}H_{40}F_3NO_7SeSiNa$, 714.1589; found 714.1595.

***t*-butyldimethylsilyl 4-*O*-benzyl- 3-*O*-[(benzyloxy)methyl], 2,6-dideoxy-6-phenylseleno-2-trifluoroacetamide-∃-D-glucopyranoside (61b).**



To a stirred 0 °C solution of **60** (0.027 g, 0.040 mmol) in 0.7 mL of THF was added NaH (80% in oil, 0.003 g, 0.100 mmol). After 30 min., BnBr (0.0095 mL, 0.08 mmol) and NBu_4I (0.003 g, 0.008 mmol) were added and the temperature maintained at 0 °C for 1 h. The reaction was then warmed to room temperature. After 4 h, 0.05 mL of AcOH was slowly added at 0 °C and the reaction mixture was diluted with 5 mL of EtOAc and washed with 5 mL of H_2O, 5 mL of satd. $NaHCO_3$ and 5 mL of satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified by preparative thin layer chromatography (hexanes:EtOAc, 4:1) to afford **61b** (0.020 g, 67%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.37 (m, 10H, Bn/ ArH of BOM), 7.25 (m, 5H, SePh), 5.40 (dd, 1H, J = 6.4, 3.1 Hz, H1), 4.74 (d, 1H, J = 7.0 Hz, O-C$\underline{H}_2$-Ph), 4.59 (m, 1H, O-C$\underline{H}_2$-Ph), 4.53 (m, 4H, C$\underline{H}_2$-Ph), 4.68 (s, 2H, O-C$\underline{H}_2$-O-Bn), 4.67 (m, 1H, H3), 3.90 (d, 1H, J= 2.1 Hz, H4), 3.61 (dd, 1H, J= 10.9, 7.9, Hz, H2), 3.54 (m, 1H, H5), 3.12 (dd, 1H, J= 12.6, 6.8 Hz, H6), 2.89 (dd, 1H, J= 12.4, 6.7 Hz, H6), 0.86 (s, 9H, tBu), 0.12 (s, 3H, Me), 0.08 (s, 3H, Me). ^{13}C NMR ($CDCl_3$) δ 157.84, 157.55, 138.44, 137.59, 132.61, 130.46, 129.64, 128.96, 128.79, 128.72, 128.35, 128.26, 128.06, 127.45, 117.27, 114.98, 95.43, 94.03, 76.73, 75.26, 74.92, 74.55, 70.42, 60.82, 56.38, 28.32, 25.96, 18.23, -3.60, -5.02. MS (ES, Na^+): m/z (relative intensity) 762.1 (100). HRMS (M + Na^+) calcd for $C_{35}H_{44}NO_6SeSiF_3Na$, 762.1953; found 762.1951.

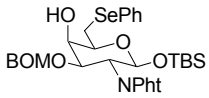
4-*O*-Acetyl, 3-*O*-[(benzyloxy)methyl]-2, 6-dideoxy-6-phenylseleno-2-trifluroracetamido-∀-D-galactopyranosyl-1-dibenzyl phosphate (62).



To a stirred 0 °C solution of **61a** (0.075 g, 0.108 mmol) in 1.5 mL of CH_3CN and pyridine (0.4 mL, 5.193 mmol) in a Nalgene bottle was added 0.15 mL HF·pyridine and the temperature maintained for 1 h. The reaction was allowed to warm to room temperature. After 5 h, the reaction was diluted with 20 mL of CH_2Cl_2 and extracted with 20 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified by flash column chromatography (hexanes:EtOAc, 3:1) to afford the free C-1 alcohol (0.061 g, 86%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.50 (m, 2H, SePh), 7.34-7.26 (m, 18H, SePh/ ArH of BOM/Bn), 6.87 (d, 1H, N-H), 5.50 (dd, 1H, J = 2.4 Hz, H1), 5.28 (d, 1H, J = 3.4 Hz, H4), 4.80 (m, 1H, O-CH_2-Ph/Bn), 4.61-4.53 (d, 3H, O-CH_2-Ph/Bn/O-CH_2-O-Bn), 4.44 (m, 1H, H2), 4.20 (m, 1H, H5), 4.08 (dd, 1H, J = 3.0 Hz, H3), 3.68 (d, 1H, J = 2.0 Hz, -OH), 3.02 (dd, 1H, J = 12.7, 8.1 Hz, H6), 2.83 (dd, 1H, J = 12.7, 5.8 Hz, H6), 2.14 (s, 3H, OAc). To a stirred -78°C solution of the free alcohol (0.135 g, 0.23 mmol) in 8 mL of THF was added a freshly prepared solution of 0.21M LDA (1.68 mL, 0.35 mmol). After 15 min, a -78°C solution of TBPP (0.164 g, 0.300 mmol) in 4 mL of THF was added to the free alcohol solution. After 15 min, the reaction was warmed to 0°C. After 2.5 h, the reaction was warmed to room temperature and diluted with 100 mL of CH_2Cl_2 and washed with 100 mL of satd. $NaHCO_3$ twice and once with 100 mL of

satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (hexanes:EtOAc, 3:1) to afford **62** (0.161 g, 82%; 70%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.44 (m, 2H, SePh), 7.31 (m, 5H, ArH of BOM), 7.27 (m, 10H, Bn), 7.20 (m, 3H, SePh), 6.87 (d, 1H, J = 8.5 Hz, N-H), 5.79 (dd, 1H, J = 6.0, 3.2 Hz, H1), 5.52 (d, 1H, J = 2.3 Hz, H4), 4.49 (m, 4H, O-CH_2-Ph/Bn), 4.75 (d, 1H, J = 7.2 Hz, O-CH_2-O-Bn), 4.58 (m, 2H, O-CH_2-Ph/BOM), 4.51 (d, 1H, O-CH_2-O-Bn), 4.45 (m, 1H, H3), 4.11 (m, 1H, J = 6.9 Hz, H5), 3.91 (dd, 1H, J = 11.0, 3.1 Hz, H2), 2.99 (dd, 1H, J = 12.9, 7.2 Hz, H6), 2.81 (dd, 1H, J = 12.9, 6.9 Hz, H6), 2.12 (s, 3H, OAc). ^{13}C NMR ($CDCl_3$) δ 170.76, 158.32, 158.02, 137.46, 135.80, 135.68, 133.64, 133.32, 130.32, 129.92, 129.47, 129.30, 129.15, 128.77, 128.68, 128.63, 128.30, 128.03, 117.32, 115.03, 96.67, 93.27, 71.87, 71.38, 70.64, 70.49, 68.17, 49.83, 30.29, 27.56, 21.33, 0.59. ^{19}F NMR δ 0.43. ^{31}P NMR δ -1.23. MS (ES, Na^+): m/z (relative intensity) 860.1 (100). HRMS (M + Na^+) calcd for $C_{38}H_{39}F_3NO_{10}PSeNa$, 860.1327; found 860.1329.

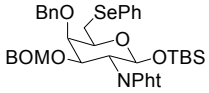
_t_-Butyldimethylsilyl 3-_O_-[(benzyloxy)methyl]- 2,6-dideoxy-6-phenylseleno-2-trifluoroacetamide-∃-D-glucopyranoside (66).



To a stirred solution of **40b** (0.09 g, 0.12 mmol) in 2 mL of dry THF was added 1M NaOMe solution (0.12 mL, 0.120 mmol). After 1 h, 0.35 g of Dowex 50W H^+ form resin (2.1 meq/mL) was added and gently stirred for 20 min. The mixture was filtered and the filtrate concentrated. The crude product was purified by flash column

chromatography (hexanes:EtOAc, 4:1) to afford **66** (0.06 g, 71%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.81 (d, 1H, Pht), 7.67 (m, 3H, Pht), 7.51 (m, 2H, ArH of BOM), 7.36 (m, 1H, ArH of BOM), 7.28 (m, 2H, SePh), 7.25 (m, 3H, SePh), 7.09 (m, 2H, ArH of BOM), 5.31 (dd, 1H, J = 7.9 Hz, H1), 4.76 (d, 1H, J = 7.1 Hz, O-C$\underline{H}_2$-Ph), 4.66 (m, 1H, O-C$\underline{H}_2$-Ph), 4.58 (dd, 1H, J = 11.1, 3.1 Hz, H3), 4.45 (dd, 1H, J= 11.1, 7.9, Hz, H2), 4.41 (s, 1H, O-C$\underline{H}_2$-O-Bn), 4.32 (s, 1H, O-C$\underline{H}_2$-O-Bn), 4.18 (d, 1H, H4), 3.76 (m, 1H, H5), 3.35 (dd, 1H, J= 12.7, 7.3 Hz, H6), 3.21 (dd, 1H, J= 12.7, 6.4 Hz, H6), 2.47 (d, 1H, J = 2.5 Hz, -OH), 0.66 (s, 9H, tBu), 0.08 (s, 3H, Me), 0.01 (s, 3H, Me). ^{13}C NMR ($CDCl_3$) δ 168.80, 167.90, 136.90, 133.97, 132.21, 131.52, 130.18, 129.16, 128.51, 128.32, 127.65, 127.40, 126.93, 123.33, 122.92, 93.97, 93.60, 74.93, 74.17, 69.91, 68.02, 65.30, 54.15, 27.71, 25.29, 17.45, -4.07, -5.68. MS (ES, Na^+): m/z (relative intensity) 706.1 (100). HRMS (M + Na^+) calcd for $C_{34}H_{41}NO_7SeSiNa$, 706.1715; found 706.1719.

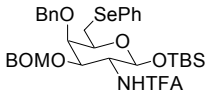
_t_-Butyldimethylsilyl 4-_O_-benzyl- 3-_O_-[(benzyloxy)methyl]-2,6-dideoxy-6-phenylseleno-2-phthalimido-∃-D-glucopyranoside (67).



To a stirred 0 °C solution of **66** (1.24 g, 1.82 mmol) in 50 mL of THF was added NaH (80% in oil, 0.065 g, 2.728 mmol). After 30 min, BnBr (0.43 mL, 3.64 mmol) and NBu_4I (0.130 g, 0.364 mmol) were added and the solution was warmed to room temperature. After 22 h, the reaction was diluted with 100 mL of EtOAc and washed with 75 mL of H_2O, satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified by flash column chromatography (hexanes:EtOAc, 5:1) to afford **67** (1.06 g, 76%) as a

colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.70 (m, 2H, Pht), 7.46-7.21 (m, 15H, Pht/SePh/Bn/ ArH of BOM), 7.00 (m, 2H, PhSe), 5.33 (dd, 1H, J = 7.3 Hz, H1), 4.98 (d, 1H, J = 11.3 Hz, O-C$\underline{H}_2$-Ph), 4.78 (m, 1H, O-C$\underline{H}_2$-Ph), 4.70-4.59 (m, 3H, H3/H2/H5), 4.55 (m, 4H, C$\underline{H}_2$-Ph), 4.33 (s, 2H, O-C$\underline{H}_2$-O-Bn), 3.16 (m, 1H, H6), 4.03 (d, 1H, J= 1.9 Hz, H4), 3.24 (dd, 1H, J= 12.5, 6.9 Hz, H6), 2.92 (dd, 1H, J= 12.5, 6.7 Hz, H6), 0.86 (s, 9H, tBu), 0.12 (s, 3H, Me), 0.08 (s, 3H, Me). ^{13}C NMR ($CDCl_3$) δ 168.93, 167.94, 138.22, 137.16, 133.86, 132.23, 132.10, 131.66, 130.27, 129.18, 128.55, 128.40, 128.33, 128.24, 128.14, 128.07, 128.01, 127.83, 127.72, 127.47, 127.18, 126.89, 123.27, 122.82, 93.98, 93.74, 76.04, 74.76, 74.53, 74.42, 69.75, 54.74, 53.40, 28.11, 26.18, 17.50, -4.03, -5.58. MS (ES, Na^+): m/z (relative intensity) 796.2 (100). HRMS (M + Na^+) calcd for $C_{39}H_{45}NO_7SeSiNa$, 796.2185; found 796.2181.

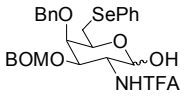
_t_-Butyldimethylsilyl 4-_O_-benzyl- 3-_O_-[(benzyloxy)methyl]-2,6-dideoxy-6-phenylseleno-2-trifluoroacetamide-∃-D-glucopyranoside (61b).



To a stirred suspension of **67** (0.125 g, 0.161 mmol) in 5 mL of EtOH in a Schlenk tube was added $H_2NNH_2 \cdot H_2O$ (0.73 mL, 15.2 mmol). The tube was placed under a gentle vacuum, the tube sealed, and heated to 100 °C. After 35 h, the reaction was cooled and the tube opened. The reaction mixture was diluted with 40 mL of EtOAc and washed with 20 mL of satd. $NaHCO_3$ solution and the aqueous extract washed with 20 mL of EtOAc. The combined organic extracts were washed with 50 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting free amine was purified using a short silica gel plug (hexanes:EtOAc, 1:1) to afford the free

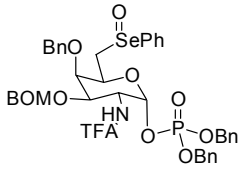
amino alcohol (0.094 g) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.41 (m, 2H, Bn), 7.35-7.25 (m, 13H, Bn/ ArH of BOM/SePh), 4.90 (d, 2H, O-C$\underline{H}_2$-Ph), 4.82 (m, 1H, O-C$\underline{H}_2$-Ph), 4.72 (d, 1H, C$\underline{H}_2$-Ph), 4.64 (s, 2H, O-C$\underline{H}_2$-O-Bn), 4.57 (s, 2H, O-C$\underline{H}_2$-O-Bn), 4.35 (d, 1H, J = 7.5 Hz, H1), 3.87 (d, 1H, J= 2.1 Hz, H4), 3.51 (dd, 1H, J = 10.8, 2.6 Hz, H3), 3.48 (m, 1H, H5), 3.22 (m, 1H, H2), 3.20 (dd, 1H, J= 12.5, 6.9 Hz, H6), 2.90 (dd, 1H, J= 12.5, 6.6 Hz, H6), 1.57 (bs, 3H, NH_2), 0.92 (s, 9H, tBu), 0.16 (s, 3H, Me), 0.08 (s, 3H, Me). ^{13}C NMR ($CDCl_3$) δ 137.38, 136.42, 131.10, 129.31, 128.25, 128.11, 127.67, 127.47, 127.26, 127.18, 127.06, 126.82, 126.77, 126.64, 126.55, 126.27, 125.91, 125.82, 98.54, 93.13, 80.36, 73.58, 73.04, 69.02, 64.21, 59.34, 52.38, 28.66, 27.22, 24.82, 17.01, -4.76, -6.21. MS (ES, Na^+): m/z (relative intensity) 644.2 (100). HRMS (M + Na^+) calcd for $C_{39}H_{45}NO_5SeSiNa$, 644.2305; found 644.2310. To a stirred 0 °C solution of the free amino alcohol (0.094 g, 0.146 mmol) in 1.0 mL of pyridine was added TFAA (0.10 mL, 0.731 mmol) and the temperature maintained at 0 °C. After 1 h, the reaction was diluted to 25 mL of EtOAc and washed with 25 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified by flash column chromatography (hexanes:EtOAc, 3:1) to afford **61b** (0.100 g, 83%, 2 steps) as a colorless oil with identical ^{1}H NMR, ^{13}C NMR and Mass Spectrum data as previously described (**60** to **61b**).

4-*O*-benzyl-3-*O*-[(benzyloxy)methyl]-2, 6-dideoxy-6-phenylseleno-2-phthalimido-β-D-glucopyranoside (68).



To a stirred 0 °C solution of **61b** (0.020 g, 0.027 mmol) in 0.4 mL of dry CH_3CN and 0.15 mL of pyridine in a Nalgene bottle was added 0.05 mL of HF pyridine. After 1 h, the reaction was warmed to room temperature. After 3.5 h, the reaction was diluted with 5 mL of CH_2Cl_2 and washed with 5 mL of satd. $CuSO_4$, satd. $NaHCO_3$, H_2O and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate evaporated. The crude product was purified by flash column chromatography (hexanes:EtOAc, 3:1) to afford **3.10C** (0.015 g, 89%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.44 (m, 3H, Bn/Ph), 7.32 (m, 12H, Bn/Ph), 7.25 (m, 5H, SePh), 6.77 (d, 1H, J= 8.5 Hz, N-H), 5.35 (d, 1H, J= 2.1 Hz, H4), 4.95 (d, 1H, J = 11.3 Hz, O-CH_2-Ph), 4.82 (m, 1H, O-CH_2-Ph), 4.75 (m, 1H, O-CH_2-Ph), 4.65 (m, 3H, CH_2-Ph), 4.59 (m, 1H, H1), 4.47 (d, 1H, J= 11.4, CH_2-Bn), 4.06-4.00 (m, 3H, H5/H2/CH_2-Ph), 3.61 (dd, 1H, J= 10.9, 7.9 Hz, H2), 3.54 (m, 1H, H5), 3.11 (dd, 1H, J = 12.6, 6.4 Hz, H6), 3.05 (m, 1H, H3), 2.95 (dd, 1H, J= 12.6, 7.8 Hz, H6). ^{13}C NMR ($CDCl_3$) δ 157.73, 157.44, 138.24, 137.24, 132.88, 130.06, 129.56, 129.06, 128.95, 128.78, 128.61, 128.40, 128.23, 128.16, 127.98, 127.55, 117.29, 115.00, 93.79, 91.79, 75.92, 75.19, 74.72, 71.13, 70.26, 49.91, 28.10. MS (ES, Na^+): m/z (relative intensity) 648.2 (100). HRMS (M + Na^+) calcd for $C_{29}H_{30}NO_6SeF_3Na$, 648.1088; found 648.1095.

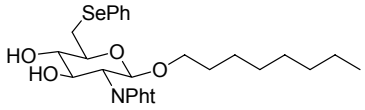
4-O-Benzyl, 3-*O*-[(benzyloxy)methyl]-2, 6-dideoxy-6-phenylselenoxo-2-trifluroracetamido-∀-D-galactopyranosyl-1-dibenzyl phosphate (69).



To a stirred suspension of 1-*H*-tetrazole (0.006 mg, 0.080 mmol) in 0.25 mL of CH_2Cl_2 was added $(i\text{Pr})_2\text{NP}(\text{OBn})_2$ (0.014 mL, 0.044 mmol). After 15 min, the reducing sugar **68** (0.025 g, 0.040 mmol) in 0.25 mL of CH_2Cl_2 was added to the stirred solution. After 7 h, the reaction was diluted to 3 mL of CH_2Cl_2 and washed with 3 mL of satd. $NaHCO_3$, H_2O, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified by flash column chromatography (hexanes:EtOAc, 3:1, 1% NEt_3) to afford the phosphite (0.02 g, 59%) as a colorless oil/solid: ^{1}H NMR ($CDCl_3$) δ 7.64-7.20 (m, 25H, SePh/ ArH of BOM/Bn), 6.74 (d, 1H, J = 8.1 Hz, N-H), 5.69 (dd, 1H, J = 7.7, 3.2 Hz, H1), 4.96 (d, 1H, J = 5.1 Hz, H4), 4.87-4.60 (m, 10H, O-CH_2-Ph-Bn/O-CH_2-O-Bn/O-CH_2-Ph-BOM), 4.45 (m, 1H, H3), 4.09 (m, 1H, H5), 3.91 (dd, 1H, J = 6.0 Hz, H2), 3.01 (dd, 1H, J = 12.2, 5.4 Hz, H6), 2.73 (dd, 1H, H6). ^{13}C NMR ($CDCl_3$) δ 137.55, 132.14, 129.17, 128.55, 128.47, 128.37, 128.15, 128.00, 127.87, 127.57, 127.38, 127.34, 127.03, 93.58, 75.91, 74.87, 74.04, 71.88, 69.80, 64.47, 50.73, 49.68, 45.91, 27.07, 0.95. ^{19}F NMR δ 0.74. ^{31}P NMR δ 141.03. MS (ES, Na^+): m/z (relative intensity) 892.1 (100). HRMS (M + Na^+) calcd for $C_{43}H_{43}NO_8SePF_3Na$, 892.1741; found 892.1753. To a stirred solution of the phosphite (0.020 g, 0.023 mmol) in 3.5 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.004 g, 0.050 mmol) and $NaIO_4$ (0.014 g, 0.069 mmol). A white precipitate formed during the course of the reaction. After 1.5 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. An additional 3 mL of H_2O was added to the filtrate and the aqueous extract was washed 2 times with 5 mL of CH_2Cl_2. The combined organic layers were washed with satd. 10 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated to afford **69** (0.018 g, 90%; 53%, 2 steps) as a colorless oil/solid: ^{1}H

NMR ($CDCl_3$) δ 7.54-7.17 (m, 25H, SePh/ ArH of BOM/Bn), 6.95 (d, 1H, N-H), 5.84 (dd, 1H, J = 9.4, 5.8 Hz, H1), 4.98 (d, 1H, H4), 5.06-4.63 (m, 10H, O-CH_2-Ph-Bn/O-CH_2-O-Bn/O-CH_2-Ph-BOM), 4.42 (m, 1H, H3), 4.03 (m, 1H, H5), 3.71 (dd, 1H, H2), 3.00 (dd, 1H, H6), 2.52 (dd, 1H, H6). ^{13}C NMR ($CDCl_3$) δ 137.22, 132.04, 132.30, 130.06, 129.25, 128.50, 127.89, 127.56, 93.82, 91.72, 75.82, 75.54, 74.79, 73.91, 72.98, 69.82, 69.29, 68.11, 53.37, 49.71, 0.98. ^{19}F NMR δ 0.77. ^{31}P NMR δ -1.05. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{43}H_{43}NO_{10}SePF_3Na$; found 922.4 (100).

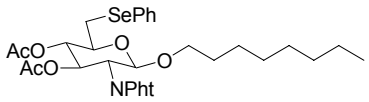
Octyl 2, 6-dideoxy-2-phthalamido-6-phenylseleno-Ξ-D-glucopyranoside (70).



To a stirred solution of **33** (0.42 g, 0.63 mmol) in 12 mL of THF:MeOH (1:1) was added 0.5M NaOMe solution (0.07 mL, 1.26 mmol). After 16 h, the reaction was quenched with 0.50 g of Dowex 50W H^+ form resin (2.1 meq/mL) and stirred gently for 15 min. The mixture was filtered and the filtrate concentrated. The resulting oil was purified by flash column chromatography (hexanes:EtOAc, 1:1) to afford **70** as a colorless oil (0.23 g, 66%): ^{1}H NMR ($CDCl_3$) δ 7.73 (d, 2H, NPht), 7.62 (m, 2H, NPht), 7.51 (m, 2H, SePh), 7.20 (m, 3H, SePh), 5.09 (d, 1H, J = 8.4 Hz, H1), 4.23 (m, 1H, H3), 4.06 (dd, 1H, J = 10.8, 8.4 Hz, H2), 3.67 (d, 2H, J = 5.6 Hz, -OH), 3.64 (m, 1H, CH_2-octyl), 3.62 (d, 1H, J = 8.9, 2.7 Hz, H4), 3.40 (ddd, 1H, J = 8.9, 3.7 Hz, H5), 3.33 (dd, 2H, J = 12.9, 2.7 Hz, H6), 3.30 (m, 1H, CH_2-octyl), 1.36-1.32 (bs, 2H, CH_2-octyl), 1.23-0.96 (bs, 10H, CH_2-octyl), 0.92 (t, 3H, CH_3-octyl). ^{13}C NMR ($CDCl_3$) δ 171.31, 168.42,

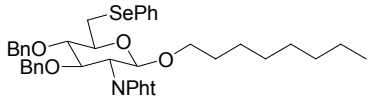
133.97, 132.06, 131.50, 130.95, 128.92, 126.52, 123.32, 98.01, 75.50, 75.47, 71.77, 69.59, 60.40, 56.74, 31.58, 29.48, 29.15, 29.05, 25.72, 22.51, 20.96, 14.09, 13.99. MS (ES, Na^+): m/z (relative intensity) 584.1 (100). HRMS (M + Na^+) calcd for $C_{28}H_{35}NO_6SeNa$, 584.1527; found 584.1528.

Octyl 3, 4, -di-*O*-acetyl-2, 6-dideoxy-6-phenylseleno-2-phthalimido-β-D-glucopyranoside (71a).



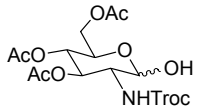
Compound **70** (0.09 g, 0.16 mmol) was dissolved in 0.3 mL of Ac_2O and 0.3 mL of pyridine. After 5 h, the reaction was diluted with 25 mL of EtOAc and washed with satd. $NaHCO_3$, H_2O, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using a short silica gel plug (hexanes:EtOAc, 1:1) to afford **71a** (0.10 g, 99%) as a white powder. ^1H NMR ($CDCl_3$) δ 7.90-7.83 (m, 5H, Pht/SePh), 7.79-7.76 (m, 3H, SePh), 7.72 (m, 2H, Pht), 5.75 (dd, 1H, J = 10.6, 9.1 Hz, H4), 5.30 (d, 1H, J = 8.5 Hz, H1), 5.05 (m, 1H, H3), 4.30 (dd, 1H, J= 10.7, 8.6 Hz, H2), 3.87 (m, 1H, H5), 3.73 (m, 1H, C$\underline{H}_2$-octyl), 3.39 (m, 1H, C$\underline{H}_2$-octyl), 3.12-3.08 (dd, 1H, J = 12.9, 8.3 Hz, H6), 3.08-3.04 (m, 1H, H6), 2.00 (s, 3H, OAc), 1.85 (s, 3H, OAc), 1.40 (bs, 2H, CH_2-octyl), 1.24-0.95 (bs, 10H, CH_2-octyl), 0.96 (bs, 3H, CH_3). ^{13}C NMR ($CDCl_3$) δ 170.23, 169.74, 134.35, 132.66, 129.14, 127.11, 123.64, 97.94, 73.79, 73.14, 70.73, 69.99, 54.88, 31.66, 29.32, 29.22, 29.13, 25.80, 22.61, 20.77, 20.52, 14.07. MS (ES, Na^+): m/z (relative intensity) 666.1 (100). HRMS (M + Na^+) calcd for $C_{32}H_{39}NO_8Na$, 668.1739; found 668.1740.

Octyl 3, 4, -di-*O*-benzyl-2, 6-dideoxy-6-phenylseleno-2-phthalimido-β-D-glucopyranoside (71b).



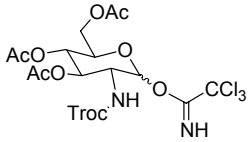
To a stirred 0 °C solution of **70** (0.135 g, 0.242 mmol) in 8 mL of THF was added NaH (0.023 g, 0.970 mmol). After 30 min, the reaction had BnBr (0.11 mL, 0.97 mmol) and Bu_4NI (0.44 g, 1.21 mmol) added to it. The solution was warmed to room temperature. After 17 h, the reaction was diluted with 40 mL of EtOAc and washed with 20 mL of satd. $NaHCO_3$, H_2O, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using flash column chromatography (hexanes:EtOAc, 5:1) to afford **71b** (0.110 g, 63%) as a colorless oil: ^1H NMR ($CDCl_3$) δ 7.65-7.48 (m, 2H, Pht), 7.32 (m, 2H, Pht), 7.30-7.21 (m, 10H, Bn), 7.00 (m, 2H, SePh), 6.87 (m, 2H, SePh), 5.09 (d, 1H, J = 8.5 Hz, H1), 4.90 (d, 1H, J= 11.0, C$\underline{H}_2$-Bn), 4.79 (d, 1H, J= 12.0, C$\underline{H}_2$-Bn), 4.65 (d, 1H, J= 11.1, C$\underline{H}_2$-Bn), 4.42 (d, 1H, J= 12.0, C$\underline{H}_2$-Bn), 4.33 (dd, 1H, J = 10.7, 8.6 Hz, H4), 4.15 (dd, 1H, J = 10.7 8.5, Hz, H4), 3.72 (dd, 1H, J= 9.4, 2.5 Hz, H5), 3.56 (m, 1H, C$\underline{H}_2$-octyl), 3.56 (m, 1H, H2), 3.34-3.30 (m, 2H, H6/C$\underline{H}_2$-octyl), 3.04 (dd, 1H, J = 12.6, 8.4 Hz, H6), 1.56 (bs, 2H, CH_2-octyl), 1.14-0.90 (bs, 10H, CH_2-octyl), 0.80 (bs, 3H, CH_3). ^{13}C NMR ($CDCl_3$) δ 137.81, 137.70, 132.08, 131.03, 128.95, 128.48, 128.00, 127.93, 127.82, 127.29, 126.59, 97.99, 83.21, 79.34, 75.16, 74.94, 74.79, 69.55, 56.00, 31.57, 29.62, 29.15, 29.03, 25.72, 22.51, 13.98. MS (ES, Na^+): m/z (relative intensity) 764.2 (100). HRMS (M + Na^+) calcd for $C_{49}H_{43}NO_6SeNa$, 764.2466; found 764.2462.

3, 4, 6-tri-*O*-Acetyl-2-deoxy-2-(2, 2, 2-trichloroethoxycarbonyl) amido-β-D-glucopyranoside (76).



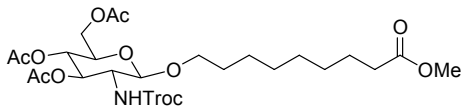
To a stirred solution of $(H_2NCH_2)_2$ (0.21 mL, 3.44 mmol) and AcOH (0.23 mL, 4.01 mmol) in 100 mL of THF was added **43** (1.50 g, 2.87 mmol). After 25 h, the solution was diluted with 60 mL of H_2O and the aqueous extract was washed three times with 120 mL of CH_2Cl_2. The combined organic extracts were washed with 360 mL of 0.1M HCl solution, 360 mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered, and the filtrate concentrated. The crude product was purified with flash column chromatography (hexanes:EtOAc, 1:1) to afford **76** (1.28 g, 92 %) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 5.50 (dd, 1H, J= 9.8 Hz, NH), 5.33-5.26 (m, 3H, H1/H3/H4), 5.09 (dd, 1H, J = 9.5 Hz, H2), 4.77 (d, 1H, J= 12.0 Hz, CH_2-Troc), 4.62 (s, 1H, CH_2-Troc), 4.58 (m, 1H, H5), 4.22-4.19 (m, 2H, H6/H6), 3.98 (m, 1H, OH), 2.09-1.97 (s, 9H, Ac). ^{13}C NMR ($CDCl_3$) δ 169.92, 154.66, 95.75, 92.06, 74.91, 71.25, 68.71, 67.89, 62.45, 54.58, 14.54.

Trichloroacetimido 3, 4, 6-tri-*O*-acetyl-2-deoxy-2-(2, 2, 2-trichloroethoxycarbonyl) amido-α, β-D-glucopyranoside (77).



To a stirred solution of **76** (0.183 g, 3.800 mmol) in 20 mL of CH_2Cl_2 were added CCl_3CN (9.50 mL, 95.2 mmol) and K_2CO_3 (0.79 mg, 5.70 mmol). After 48 h, the reaction was filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (hexanes:EtOAc, 1.5:1) to afford **77** (0.22 g, 96%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 8.83 (s, 1H, N<u>H</u>), 5.79 (d, 1H, J = 3.6 Hz, H1), 5.40-5.20 (m, 3H, H3, H4, H2), 4.66 (m, 2H, C<u>H</u>$_2$-Troc), 4.31-4.11 (m, 3H, H5, H6, H6) 1.94-1.78 (m, 9H, OAc). ^{13}C NMR ($CDCl_3$) δ 171.29, 170.75, 169.56, 160.54, 154.55, 109.99, 95.64, 94.74, 90.95, 78.01, 77.58, 77.15, 74.84, 70.45, 67.87, 61.69, 60.60, 54.04, 21.25, 20.90, 20.83, 14.46. MS (ES, Na^+): m/z (relative intensity) HRMS (M + Na^+) calcd for $C_{17}H_{22}NO_{10}Cl_6Na$, 646.9; found 646.9 (100).

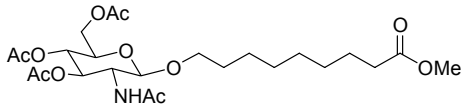
(8-Methoxylcarbonyloctyl) 3, 4, 6-tri-*O*-acetyl-2-deoxy-2-(2, 2, 2-trichloroethoxycarbonyl) amido-∃-D-glucopyranoside (78).



To a stirred 0°C solution of **77** (0.45 g, 0.72 mmol) in 10 mL of THF, 8-methoxylcarbonyloctanol (0.13 mL, 0.55 mmol) and 0.45 g of 4Å powdered sieves was added freshly distilled TMS-OTf (0.013 mL, 0.072 mmol). After 1 hr, the reaction was quenched with 5 drops of NEt_3, filtered and the filtrate concentrated. The resulting residue was dissolved in 40 mL of EtOAc and washed with 40 mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with flash column chromatography ($CHCl_3$:EtOAc, 7:1) to afford **78** (0.38 g, 92%) as an oil: ^{1}H NMR ($CDCl_3$) δ 5.75 (s,

1H, J = 9.0 Hz, H1), 5.24 (m, 1H, H4), 4.98 (m, 1H, H3), 4.70 (d, 1H, J = 11.9 Hz, NH), 4.60-4.57 (m, 2H, CH_2-Troc), 4.22 (m, 1H, H2), 4.04 (m, 1H, H5), 3.79 (m, 1H, H6), 3.59 (s, 3H, OMe), 3.41 (m, 1H, H6), 2.23 (s, 3H, OAc), 2.20-2.01 (m, 6H, OAc), 1.51 (bs, 7H, octyl), 1.18 (bs, 9H, octyl). ^{13}C NMR ($CDCl_3$) δ 174.81, 171.15, 170.98, 169.92, 164.13, 154.60, 101.13, 95.92, 92.44, 74.74, 72.70, 72.46, 71.97, 70.54, 69.25, 63.15, 62.55, 60.79, 56.55, 51.87, 34.36, 33.01, 29.71, 29.53, 29.39-29.18, 28.56, 26.01, 25.77, 25.16, 21.39, 21.11, 21.01, 14.52. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{37}H_{35}NO_9SeNa$, 740.1375; found 672.0 (100).

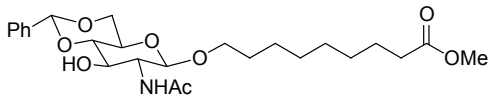
(8-Methoxylcarbonyloctyl)-2-acetamido-3, 4, 6-tri-*O*-acetyl-2-deoxy-∃-D-glucopyranoside (79).



To a stirred solution of **78** (0.15 g, 0.23 mmol) in 3 mL of AcOH was added Zn dust (1.01 g, 15.43 mmol). After 54 hours, Chelex 100 resin was added and the reaction was stirred for 1 h, filtered and the filtrate concentrated. The resulting oil was dissolved in 30 mL of EtOAc and washed with 15 mL of satd. $NaHCO_3$ and NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product (0.105 g) was taken on without purification as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.46 (bs, 3H, NH_3), 5.38 (m, 1H, H4), 4.97 (m, 1H, H3), 4.73 (d, 1H, J = 7.7 Hz, H1), 4.24 (dd, 1H, J = 12.3, 4.5 Hz, H6), 4.09 (s, 1H, CH_2-octyl), 4.04 (m, 1H, H6), 3.86-3.68 (m, 2H, H5/H2), 3.62 (s, 3H, OMe), 2.26 (bs, 6H, OAc), 2.06 (s, 3H, OAc), 1.54 (bs, 10H, octyl), 1.21 (bs, 5H, octyl). The free amine (0.105 g, 0.22 mmol) was dissolved in 3

mL of dry pyridine and 3 mL of Ac_2O. After 20 h, the reaction was diluted with 25 mL of EtOAc and washed with 25 mL of satd. $CuSO_4$, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (hexanes:EtOAc, 5:1) to afford **79** (0.095 g, 78%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 5.82 (d, 1H, J = 8.6 Hz, NH), 5.29, (m, 1H, H3), 5.02 (m, 1H, H4), 4.68 (d, 1H, J = 8.3 Hz, H1), 4.23 (dd, 1H, J = 12.3, 4.7 Hz, H6), 4.12-4.05 (m, 2H, H6, CH_2-octyl), 3.83-3.79 (m, 2H, H5/H2), 3.63 (s, 3H, OMe), 3.42 (m, 1H, CH_2-octyl), 2.26 (s, 3H, OAc). 2.01-1.98 (bs, 10H, OAc), 1.54 (bs, 5H, octyl), 1.22 (bs, 5H, OAc). ^{13}C NMR ($CDCl_3$) δ 174, 29, 171.10, 170.74, 170.14, 169.38, 100.58, 72.27, 71.62, 69.78, 68.68, 62.12, 60.32, 54.79, 51.40, 33.94, 29.26, 29.02-28.87, 25.63, 24.75, 23.21, 20.97, 20.68-20.57, 14.10.

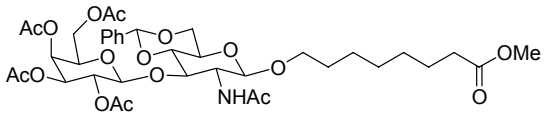
(8-Methoxylcarbonyloctyl) 2-Acetamido-4, 6-*O*-benzylidene-2-deoxy-∃-D-glucopyranoside (80).



To a stirred solution of **79** (0.25 g, 0.48 mmol) in 4 mL of MeOH and 1.5 mL of THF was added 1M NaOMe solution (0.48 mmol). After 1.25 h, 1.40 g of Dowex 50W H^+ form resin (2.1 meq/mL) was added and gently stirred for 20 minutes. The reaction mixture was filtered and the filtrate concentrated. To a suspension of the resulting triol in 5 mL of CH_3CN were added $PhCH(OMe)_2$ (0.12 mL, 0.82 mmol) and pTsOH (0.001 g, 0.048 mmol). After 21 h, the reaction was placed under a gentle vacuum. After 1 hour,

the reaction had 25 mg of K_2CO_3 and was stirred for 0.5 hours. The mixture was filtered and the filtrate concentrated. The crude product was purified with flash column chromatography (CH_2Cl_2:MeOH, 15:1) to afford **80** (0.08 g, 85%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.48 (m, 2H, Ph), 7.35 (m, 3H, Ph), 6.02 (d, 1H, J = 6.5 Hz, N-H), 5.50 (s, 1H, benzylidene), 4.65 (d, 1H, J = 8.3 Hz, H1), 4.30 (dd, 1H, J = 10.4, 5.0 Hz, H3), 4.08 (m, 1H, octyl), 3.83 (m, 1H, H6), 3.75 (m, 1H, H4), 3.65 (s, 3H, OMe), 3.52 (m, 1H, octyl), 3.47-3.42 (m, 3H, H2/H5/H6), 2.29 (s, 3H, OAc), 1.57 (bs, 5H, octyl), 1.28 (bs, 9H, octyl). ^{13}C NMR ($CDCl_3$) δ 174.29, 171.75, 137.09, 129.11, 128.21, 126.30, 101.79, 100.68, 81.63, 71.09, 69.97, 68.58, 66.20, 58.80, 51.43, 33.99, 29.38, 29.07-28.93, 25.74, 24.80, 23.52. MS (ES, Na^+): m/z (relative intensity) HRMS (M + Na^+) calcd for $C_{25}H_{40}NO_8Na$, 502.1; found 502.1 (100).

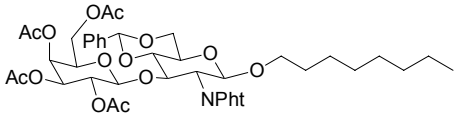
(8-Methoxylcarbonyloctyl) 2-acetamido-3-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-4, 6-*O*-benzylidene-2-deoxy-∃-D-glucopyranoside (81).



To a stirred solution of acceptor **80** (0.012 g, 0.026 mmol) in 1.0 mL of toluene:CH_3NO_2 (1:1) were added $Hg(CN)_2$ (0.02 g, 0.078 mmol) and 35 mg of $CaSO_4$. Donor **74**[81] (0.017 g, 0.041 mmol) was dissolved in 1.0 mL toluene:CH_3NO_2 (1:1) and added to the acceptor mixture and the reaction heated to 40 °C. After 47 h, the reaction was cooled and diluted with 15 mL of CH_2Cl_2 and washed with 15 mL of satd. $NaHCO_3$ solution, H_2O and satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using flash column

chromatography (CH_2Cl_2:MeOH, 15:1) to afford **81** (0.015 g, 75%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 5.80 (d, 1H, J=5.6 Hz, N-H), 5.54 (s, 1H, benzylidene), 5.18 (d, 1H, J = 8.6 Hz, H1), 4.71 (d, 1H, J = 8.2 Hz, H1'), 3.66 (s, 3H, OMe). ^{13}C NMR ($CDCl_3$) δ 229.59, 174.29, 171.73, 137.05, 129.16, 128.25, 126.32, 101.91, 100.55, 81.71, 71.15, 70.00, 68.62, 66.27, 59.28, 51.45, 34.01, 29.42, 29.09, 29.01, 28.95, 25.80, 24.82, 23.62, 23.62, 20.80, 20.63. MS (ES, Na^+): m/z (relative intensity) 832.3 (100). HRMS (M + Na^+) calcd for $C_{40}H_{57}NO_{17}Na$, 832.3368; found 832.3375.

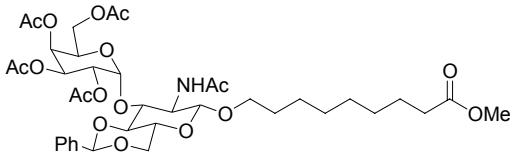
Octyl 3-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-4, 6-*O*-benzylidene-2-deoxy-2-phthalimido-∃-D-glucopyranoside (82).



To a stirred solution of acceptor **32**[47] (0.60 g, 1.22 mmol) and donor **75**[81] (0.684 g, 1.34 mmol) in 20 mL of CH_2Cl_2 at -20 °C were added 1.0 g 3Å molecular sieves and freshly distilled TMS-OTf (0.05 mL, 0.304 mmol). The reaction was allowed to warm to 0 °C for 3 h and then to room temperature. After 24 h, the reaction was quenched with 0.05 mL of NEt_3 and filtered. The filtrate was washed with 20 mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using flash column chromatography (hexanes:EtOAc, 2:1) to afford **82** (0.840 g, 83%) as a colorless foam: ^{1}H NMR ($CDCl_3$) δ 7.88 (s, 2H, Pht), 7.77 (s, 2H, Pht), 7.49 (s, 2H, Ph), 7.38 (s, 3H, Ph), 5.58 (s, 1H, benzylidene), 5.19 (d, 1H, J = 3.1 Hz, H4'), 5.14 (d, 1H, J = 8.5 Hz, H1), 4.99 (dd, 1H, J = 10.3, 8.0 Hz, H2'), 4.76-4.71 (m, 2H, H3/H3'), 4.55 (d, 1H, J = 8.0Hz, H1'), 4.37 (dd,

1H, J = 10.5, 4.8 Hz, H4), 4.30 (dd, 1H, J = 10.4, 8.6 Hz, H2), 4.03 (dd, 1H, J = 11.0, 8.3 Hz, H6'), 3.86 (m, 1H, H6'), 3.82-3.77 (m, 3H, H6/H6/C$\underline{H}_2$-octyl), 3.63 (m, 1H, H5), 3.49 (m, 1H, H5'), 3.38 (m, 1H, C$\underline{H}_2$-octyl), 2.08 (s, 3H, OAc), 2.05 (s, 3H, OAc), 1.98 (s, 3H, OAc), 1.92 (s, 3H, OAc), 1.26-1.13 (bs, 3H, C$\underline{H}_2$-octyl), 1.03-0.96 (bs, 9H, C$\underline{H}_2$-octyl), 0.82 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.23, 170.01, 169.98, 168.82, 137.05, 134.18, 129.22, 128.31, 126.00, 101.43, 100.48, 98.74, 81.08, 75.69, 70.99, 70.28, 70.01, 69.19, 68.74, 66.63, 66.31, 60.76, 56.38, 31.60, 29.20, 29.03, 29.01, 25.70, 22.53, 20.56, 20.49, 20.39, 20.06, 14.15, 13.99. MS (ES, Na^+): m/z (relative intensity) 861.9 (100). HRMS (M + Na^+) calcd for $C_{43}H_{53}NO_{16}Na$, 862.3262; found 862.3259.

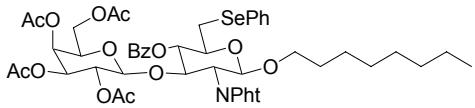
(8-Methoxylcarbonyloctyl) 2-acetamido-3-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-4, 6-*O*-benzylidene-2-deoxy-α-D-glucopyranoside (83).



To a stirred solution of acceptor **80** (0.011 g, 0.023 mmol) in 0.75 mL of CH_2Cl_2 was added 15 mg of 4Å molecular sieves. Donor **75**[81] (0.015 g, 0.030 mmol) was dissolved in 0.75 mL of CH_2Cl_2 and added to the acceptor mixture and the reaction cooled to 0 °C. Freshly distilled TMS-OTf (0.005 mL) was added. After 3 h, the reaction was quenched with 0.01 mL NEt_3, filtered and the filtrate diluted with 5.0 mL of CH_2Cl_2 and washed with 5 mL of satd. $NaHCO_3$ solution, H_2O and satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using flash column chromatography (CH_2Cl_2:MeOH, 15:1) to afford **83** (0.020 g, 81%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.48 (m, 2H, Pht), 7.34

(m, 3H, Ph), 5.82 (d, 1H, J = 7.5 Hz, N-H), 5.75 (d, 1H, J = 4.7 Hz, H1'), 5.50 (s, 1H, benzylidene), 5.8 (d, 1H, J = 3.1 Hz, H4'), 5.07 (d, 1H, J = 8.3 Hz, H1), 5.01 (dd, 1H, J = 6.4, 3.4 Hz, H3'), 4.50 (m, 1H, H3), 4.32 (m, 1H), 4.34 (m, 1H, H5), 4.24 (m, 2H, H5'/H2'), 4.06 (m, 2H, H6'/H6'), 3.84 (m, 1H, CH_2-Mco), 3.76 (m, 1H, H6), 3.66 (s, 3H, OMe), 3.52 (m, 3H, CH_2-Mco/H4/H6), 3.11 (m, 1H, H2), 2.10 (s, 3H, OAc), 2.06 (s, 3H, OAc), 2.04 (s, 3H, OAc), 2.00 (s, 3H, OAc), 1.97 (s, 3H, NHAc), 1.64 (m, 14H, CH_2-Mco). ^{13}C NMR ($CDCl_3$) δ 172.20, 171.05, 169.91, 164.39, 163.25, 129.26, 128.12, 126.05, 123.52, 109.75, 104.24, 90.69, 84.26, 70.71, 68.88, 67.50, 66.35, 61.30, 59.46, 51.43, 33.98, 29.38, 28.47, 25.94, 23.64, 20.66. MS (ES, Na^+): m/z (relative intensity) 832.3 (100). HRMS (M + Na^+) calcd for $C_{40}H_{57}NO_{17}Na$, 832.3368; found 832.3389.

Octyl 3-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-4-*O*-benzoyl-6 -phenylseleno-2-phthalamido-2-deoxy-∃-D-glucopyranoside (84).

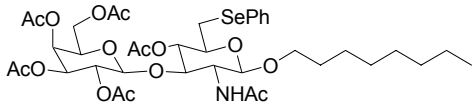


To a stirred solution of **82** (0.70 g, 0.83 mmol) in 35 mL of CCl_4 were added NBS (0.162 g, 0.916 mmol) and $BaCO_3$ (0.493 mg, 2.449 mmol). The reaction was heated to reflux and after a few minutes turned an orange color. As the reaction progressed, it became white. After 45 min, the reaction was cooled, filtered and the filtrated concentrated. The crude product was dissolved in 50 mL of CH_2Cl_2 and washed with 25 mL of H_2O 3 times and once with 25 mL of satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated to yield the bromide (0.75 g) as a white powder and taken on without any purification: ^1H NMR ($CDCl_3$) δ 8.04 (m, 2H,

Bz), 7.85 (d, 2H, NPht), 7.77 (m, 2H, NPht), 7.57 (m, 2H, Bz), 7.44 (m, 3H, Bz), 5.14 (m, 1H, H3), 5.11 (d, 1H, J = 8.5 Hz, H1), 4.97 (d, 1H, J = 4.2 Hz, H4'), 4.83 (dd, 1H, J = 10.5, 3.7 Hz, H3'), 4.54 (dd, 1H, J = 10.5, 3.5 Hz, H2'), 4.32 (m, 1H, H5'), 4.18 (d, 1H, J = 7.8 Hz, H1'), 4.09 (dd, 1H, J = 4.1 Hz, H2), 3.94 (m, 1H, H4), 3.77 (m, 1H, C$\underline{H}_2$-octyl), 3.53 (m, 2H, H6'/H6'), 3.49-3.31 (m, 4H, H5/H6/H6/ C$\underline{H}_2$-octyl), 2.09-1.75 (s, 12H, OAc), 1.41 (bs, 3H, C$\underline{H}_2$-octyl), 1.14-0.98 (bs, 9H, C$\underline{H}_2$-octyl), 0.80 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 169.92, 168.88, 164.58, 134.40, 133.32, 131.32, 129.91, 129.68, 128.25, 123.44, 100.09, 97.84, 74.64, 73.68, 72.43, 71.05, 70.65, 70.13, 66.77, 68.76, 66.09, 60.03, 55.54, 53.30, 31.46, 31.15, 28.99, 28.89, 25.58, 22.40, 20.22, 13.87. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{43}H_{52}NO_{16}BrNa$, 940.2; found 940.2 (100). To a stirred solution of the bromide (0.75 g, 0.816 mmol) in 30 mL of THF were added NEt_3 (0.37 mL, 2.692), PhSeH (0.24 mL, 2.448 mmol) and Bu_4NI (0.075 g, 0.204 mmol). The reaction was brought to reflux at 65 °C. After 16 h, the reaction was cooled and diluted to 100 mL of CH_2Cl_2 and washed with 100 mL of satd. $NaHCO_3$, H_2O and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting yellow oil was purified using flash column chromatography (hexanes:EtOAc, 2:1) to afford **84** (0.70 g, 82%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 8.03 (m, 2H, Bz), 7.87 (d, 2H, NPht), 7.79 (m, 2H, NPht), 7.58 (m, 2H, Bz), 7.46 (m, 4H, Bz/SePh), 7.19 (m, 2H, SePh), 5.23 (m, 1H, H3'), 5.07 (d, 1H, J = 8.5 Hz, H1), 5.00 (d, 1H, J = 2.9 Hz, H4'), 4.86 (dd, 1H, J = 10.3, 7.8 Hz, H2'), 4.79 (dd, 1H, J = 10.7, 8.9 Hz, H3), 4.56 (m, 1H, H5'), 4.34 (dd, 1H, J = 10.7, 8.5 Hz, H2), 4.09 (d, 1H, J = 7.8 Hz, H1'), 3.94 (m, 1H, H4), 3.72 (m, 2H, H6'/H6'), 3.52 (m, 1H, H5), 3.44 (m, 1H, H6), 3.33 (m, 2H, C$\underline{H}_2$-octyl), 3.13 (m, 1H, H6), 2.08 (s, 3H, OAc), 2.04 (s, 3H, OAc),

1.95 (s, 3H, OAc), 1.87 (s, 3H, OAc), 1.27-1.17 (bs, 3H, C$\underline{H}_2$-octyl), 1.06-1.00 (bs, 9H, C$\underline{H}_2$-octyl), 0.83 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.12, 170.04, 169.97, 169.00, 164.76, 134.49, 133.32, 132.19, 129.74, 128.99, 128.32, 126.79, 123.52, 100.23, 97.91, 74.97, 74.21, 70.81, 70.13, 69.65, 68.84, 66.18, 60.08, 55.74, 31.61, 29.05, 25.73, 22.56, 20.58, 20.36, 20.29, 14.03. MS (ES, Na^+): m/z (relative intensity) 1018.2 (100). HRMS (M + Na^+) calcd for $C_{49}H_{57}NO_{16}SeNa$, 1018.2740; found 1018.2745.

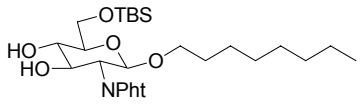
Octyl 2-acetamido-3-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)- 4-*O*-acetyl-6 -phenylseleno-2-deoxy-∃-D-glucopyranoside (85).



To a stirred solution of **84** (0.045 mg, 0.045 mmol) in 1.0 mL of EtOH in a Schlenk tube was added $H_2NNH_2{\cdot}H_2O$ (0.19 mL, 4.070 mmol). The reaction was placed under a gentle vacuum, the tube sealed and heated to 100 °C. After 18.5 h, the reaction was cooled, the tube opened and the reaction mixture concentrated and placed under vacuum for 6 h to afford the free amino alcohol (0.026 g) as a colorless oil. The product was taken on to the next step without any purification. The resulting free amino alcohol (0.026 g, 0.045 mmol) was dissolved in 3.0 mL of pyridine and 3.0 mL of Ac_2O. After 20.5 h, the reaction was diluted with 10 mL of EtOAc and washed with 10 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting light yellow oil was purified using flash column chromatography (hexanes:EtOAc, 1:4) to afford **85** (0.030 g, 78%, 2 steps) as a colorless oil/solid: ^{1}H NMR ($CDCl_3$) δ 7.48 (m, 3H, SePh), 7.26 (m,

2H, SePh), 5.89 (d, 1H, J = 7.1 Hz, NH), 5.33 (d, 1H, J = 2.5 Hz, H4'), 5.04 (dd, 1H, J = 10.1 Hz, H2'), 4.96-4.90 (m, 2H, H3'/H1), 4.80 (dd, 1H, J = 9.1 Hz, H3), 4.55-4.48 (m, 3H, H1'/H4/H5'), 3.86 (dd, 1H, J = 12.9, 6.4 Hz, H6'), 3.66 (dd, 1H, J = 8.9, 6.1 Hz, H6'), 3.74 (m, 1H, H2), 3.42 (m, 1H, CH_2-octyl), 3.12 (m, 1H, CH_2-octyl), 3.03-2.97 (m, 3H, H5/H6/H6), 2.16 (s, 3H, OAc), 2.13 (bs, 15H, OAc/NHAc), 1.52 (bs, 3H, CH_2-octyl), 1.25 (bs, 9H, CH_2-octyl), 0.86 (t, 3H, CH_3-octyl). ^{13}C NMR ($CDCl_3$) δ 175.13, 171.13, 170.88, 170.39, 170.18, 170.11, 169.67, 169.01, 132.57, 129.01, 126.91, 100.53, 98.78, 73.73, 73.04, 71.06, 70.54, 69.87, 69.39, 66.92, 61.05, 60.36, 58.39, 31.79, 29.50, 29.44, 29.29, 25.89, 23.57, 22.61, 20.99, 20.89, 20.77, 20.60, 20.49, 14.15. MS (ES, Na^+): m/z (relative intensity) 868.2 (100). HRMS (M + Na^+) calcd for $C_{38}H_{55}NO_{17}SeNa$, 868.2635; found 868.2645.

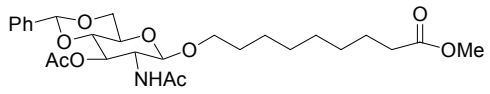
Octyl 6-*O*-*t*-butyldimethylsilyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (87).



To a stirred solution of compound **86**[47] (0.150 g, 0.356 mmol) in 1.5 mL of DMF were added imidazole (0.072 g, 1.068 mmol) and TBS-Cl (0.067 g, 0.445 mmol). After 39 h, the reaction was diluted with 10 mL of EtOAc and washed with 10 mL of H_2O and saturated NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using a short silica gel plug (EtOAc) to afford **87** (0.140 g, 74%) as a colorless oil. ^{1}H NMR ($CDCl_3$) δ 7.82 (m, 2H, Pht), 7.69 (m, 2H, Pht), 5.17 (d, 1H, J = 8.4 Hz, H1), 4.32 (dd, 1H, J = 8.1 Hz, H4), 4.08 (dd, 1H, J= 8.5, 3.5 Hz, H2), 3.97 (dd, 1H, J = 10.3, 5.0 Hz, H3), 3.87 (m, 1H, H5), 3.75

(m, 1H, -C<u>H</u>$_2$-octyl), 3.73 (bs, 1H, -OH), 3.59 (m, 1H, H6), 3.51 (m, 1H, H6), 3.37 (m, 1H, -C<u>H</u>$_2$-octyl), 2.89 (d, 1H, J = 3.6 Hz, -OH), 1.23 (bs, 2H, C<u>H</u>$_2$-octyl), 1.16-1.00 (bs, 13H, C<u>H</u>$_2$-octyl), 0.98-0.78 (s, 12H, tBu, C<u>H</u>$_3$-octyl), 0.07 (s, 6H, Me). ^{13}C NMR ($CDCl_3$) δ 168.28, 134.63, 133.33, 131.74, 123.96, 122.62, 98.78, 97.51, 75.81, 74.66, 74.14, 73.00, 72.17, 71.04, 69.64, 65.06, 56.70, 55.56, 30.25, 29.25, 28.23, 26.32, 25.32, 22.55, 21.52, 18.18, 14.50, 13.51, -5.04, -5.99. MS (ES, Na^+): m/z (relative intensity) 558.2 (100). HRMS (M + Na^+) calcd for $C_{28}H_{45}NO_7Na$, 558.2863; found 558.2869.

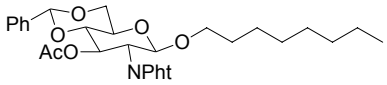
(8-Methoxylcarbonyloctyl)-2-acetamido-3-*O*-acetyl-4, 6-*O*-benzylidene-2-deoxy-Ξ-D-glucopyranoside (88a).



Compound **80** (0.018 g, 0.370 mmol) was dissolved in pyridine (1.00 mL, 0.77 mmol) and Ac_2O (1.00 mL, 1.10 mmol). After 27 h, the reaction was diluted with 5 mL of EtOAc and washed with 5 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting white oil/solid **88a** (0.016 g, 84%) was taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.43 (m, 2H, Ph), 7.34 (m, 3H, Ph), 5.74 (d, 1H, J = 9.3 Hz, N<u>H</u>), 5.50 (s, 1H, benzylidene), 5.27 (m, 1H, H4), 4.50 (d, 1H, J = 8.3 Hz, H1), 4.33 (dd, 1H, J = 10.5, 4.9 Hz, H3), 4.08 (m, 1H, H2), 3.81 (m, 2H, H5/C<u>H</u>$_2$-octyl), 3.69 (m, 1H, C<u>H</u>$_2$-octyl), 3.67 (s, 3H, OMe), 3.52 (dd, 1H, J = 9.8, 4.9 Hz, H6), 3.39 (dd, 1H, J = 6.8, 2.8 Hz, H6), 2.07 (s, 3H, OAc), 1.95 (s, 3H, OAc), 1.59 (bs, 5H, C<u>H</u>$_2$-octyl), 1.28 (bs, 10H, C<u>H</u>$_2$-octyl). ^{13}C NMR ($CDCl_3$) δ 229.59, 174.27, 171.24, 170.00, 136.97, 129.05, 128.19, 126.08, 102.00, 101.36, 78.71, 71.87, 69.95, 66.38, 54.70, 51.42, 34.02,

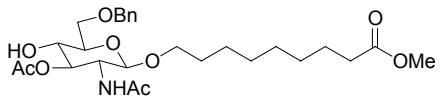
29.36, 29.36, 29.09, 29.00, 28.96, 25.67, 24.84, 23.27, 20.88. MS (ES, Na^+): m/z (relative intensity) 544.2 (100). HRMS (M + Na^+) calcd for $C_{27}H_{39}NO_9Na$, 544.2523, found; 544.2535.

Octyl 3-*O*-Acetyl-4, 6-*O*-benzylidene-2-deoxy-2-phthalimido-β-D-glucopyranoside (88b).



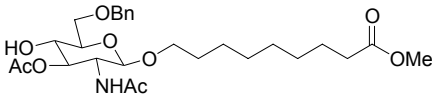
Compound **32**[47] (2.25 g, 2.45 mmol) was dissolved in 10 mL of Ac_2O and 10 mL of pyridine. After 19 h, the reaction was diluted to 75 mL of EtOAc and washed with 50 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified by flash column chromatography (hexanes:EtOAc, 3:1) to afford **88b** (1.12 g, 83%) as a colorless oil: ^1H NMR ($CDCl_3$) δ 7.81 (bs, 2H, NPht), 7.66 (bs, 2H, NPht), 7.43 (bs, 2H, Ph), 7.30 (bs, 3H, Ph), 5.89 (d, 1H, J = 9.8 Hz, H4), 5.51 (s, 1H, benzylidene), 5.43 (d, 1H, J = 8.4 Hz, H1), 4.37 (d, 1H, J = 10.2, 4.1 Hz, H3), 4.29 (dd, 1H, J = 9.1 Hz, H2), 3.83-3.74 (m, 3H, H6/H6/H5), 3.71 (m, 1H, C$\underline{H}_2$-octyl), 3.42 (m, 1H, C$\underline{H}_2$-octyl), 2.04 (s, 3H, OAc), 1.93 (s, 3H, NHAc), 1.58-1.55 (bs, 2H, C$\underline{H}_2$-octyl), 1.28-1.21 (bs, 10H, C$\underline{H}_2$-octyl), 0.85 (s, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.03, 136.99, 134.28, 134.14, 128.14, 126.22, 123.44, 101.49, 98.65, 79.28, 77.50, 77.25, 76.99, 70.13, 69.76, 68.59, 66.18, 55.39, 31.55, 29.19, 29.14, 29.10, 29.01, 25.70, 22.50, 20.47, 14.01. MS (ES, Na^+): m/z (relative intensity) 574.2 (100). HRMS (M + Na^+) calcd for $C_{31}H_{37}NO_8Na$, 574.2417; found 574.2415.

(8-Methoxylcarbonyloctyl)-2-acetamido-3-*O*-acetyl; -6-*O*-benzyl-2-deoxy-∃-D-glucopyranoside (89). Method (a).



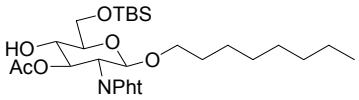
To a stirred solution of **88a** (0.022g, 0.042 mmol) in 1.0 mL of THF:CH_2Cl_2 (1:1) were added 0.02 g of 3Å molecular sieves and $NaCNBH_3$ (23mg, 0.379 mmol). Freshly prepared HCl (g) in ether was added at 0 °C until no gas was evolved. After 5 h, the reaction was filtered and the filtrate diluted to 10 mL of CH_2Cl_2 and washed with 10 mL of H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparatory thin layer chromatography (CH_2Cl_2:MeOH, 15:1) to afford **89** (0.004 g, 25%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.33 (m, 5H, Ph), 5.52 (d, 1H, J = 9.1 Hz, N<u>H</u>), 5.05 (dd, 1H, J = 10.5, 9.1 Hz, H3), 4.59 (q, 2H, J = 11.9 Hz, C<u>H</u>$_2$-Ph), 4.48 (d, 1H, J = 8.3 Hz, H1), 3.89 (m, 1H, H2), 3.82 (m, 2H. H5/CH_2-octyl), 3.76 (m, 2H, H4/CH_2-octyl), 3.66 (s, 3H, OMe), 3.53 (m, 1H, H6), 3.42 (m, 1H, H6), 2.30 (d, 1H, J = 3.0 Hz, -O<u>H</u>), 2.30 (bs, 2H, C<u>H</u>$_2$-octyl), 2.10 (s, 3H, OAc), 1.93 (s, 3H, OAc), 1.58 (bs, 5H, C<u>H</u>$_2$-octyl), 1.27 (bs, 10H, C<u>H</u>$_2$-octyl). ^{13}C NMR ($CDCl_3$) δ 174.29, 171.88, 169.99, 137.50, 128.50, 127.90, 127.74, 101.12, 75.40, 73.81, 73.77, 71.17, 70.64, 69.53, 54.70, 51.11, 51.43, 34.03, 29.39, 29.11, 29.03, 28.98, 25.75, 24.85, 23.33, 20.92. MS (ES, Na^+): m/z (relative intensity) 546.2 (100). HRMS (M + Na^+) calcd for $C_{27}H_{41}NO_9Na$, 546.2679; found 546.2679.

Method (b).



To a stirred 0 °C solution of **88a** (0.01 g, 0.06 mmol) in 0.25 mL of CH_2Cl_2 were added dropwise TES (0.0091 mL, 0.113 mmol) followed by drop wise addition of TFA (0.0087 mL, 0.114 mmol). The reaction was allowed to stir overnight at 4 °C. After 30 h, the reaction was filtered and the filtrate diluted to 5 mL of CH_2Cl_2. The filtrate had 5 mL of satd. $NaHCO_3$ solution slowly added to neutralize the TFA. The aqueous extract was washed with 5 mL of CH_2Cl_2 and the combined organic extracts washed with sat NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparatory thin layer chromatography (CH_2Cl_2:MeOH, 15:1) to afford **89** (0.005 g, 50%) as a colorless oil with identical ^1H NMR, ^{13}C NMR and mass spectrum data as identical to those reported for **89** prepared by Method (a).

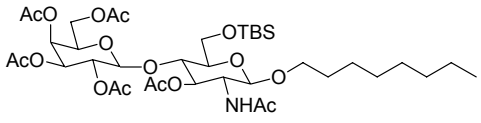
Octyl 3-*O*-acetyl-6-*O*-*t*-butyldimethylsilyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (90).



Compound **88b** (1.10 g, 1.99 mmol) was suspended in 50 mL of AcOH:H_2O (1:1) and heated to 100 °C. After 4.5 h, the reaction was cooled and concentrated. The crude product was diluted in 75 mL of EtOAc and washed with 50 mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated to afford the diol (0.89 g) as a colorless oil and taken on without any

purification. To a stirred solution of the crude diol (0.10 g, 0.22 mmol) in 2.0 mL of DMF were added TBS-Cl (0.040 g, 0.269 mmol) and imidazole (0.044mg, 0.645 mmol). After 20 h, the DMF was concentrated. The crude product was diluted to 20 mL of EtOAc and washed with 10 mL of H_2O, and satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using a short silica gel plug (EtOAc) to afford **90** (0.105 g, 81%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.86 (bs, 2H, NPht), 7.74 (bs, 2H, NPht), 5.65 (d, 1H, J = 10.6, 8.9 Hz, H4), 5.35 (d, 1H, J = 8.5 Hz, H1), 4.21 (dd, 1H, J = 10.6, 8.5 Hz, H3), 3.97-3.83 (m, 2H, H5/H2), 3.78 (m, 2H, H6/H6), 3.61 (m, 1H, C$\underline{H}_2$-octyl), 3.42 (m, 1H, C$\underline{H}_2$-octyl), 2.94 (d, J = 4.9 Hz, OH), 2.04 (s, 3H, OAc), 1.93 (s, 3H, NHAc), 1.58-1.55 (bs, 2H, C$\underline{H}_2$-octyl), 1.28-1.21 (bs, 10H, C$\underline{H}_2$-octyl), 0.85 (s, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 171.40, 170.32, 168.18, 167.78, 134.18, 134.11, 133.87, 131.37, 123.47, 123.41, 123.30, 98.09, 97.46, 76.23, 75.37, 73.77, 70.30, 70.07, 69.25, 69.04, 60.35, 55.42, 31.60, 29.29, 29.09, 25.87, 25.60, 22.52, 20.66, 17.94, 14.13. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{30}H_{47}NO_8Na$, 512.3; found 512.3 (100).

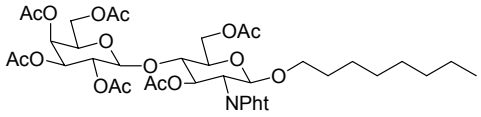
Octyl 4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-2-acetamido-3-*O*-acetyl-6-*O*-*t*-butyldimethylsilyl-2-deoxy-∃-D-glucopyranoside (93).



To a stirred solution of acceptor **91**[73] (0.028 g, 0.057 mmol) and donor **75**[81] (0.03 g, 0.06 mmol) in 3 mL of CH_2Cl_2 was added 0.10 g 3Å molecular sieves. The reaction was cooled to -30°C and freshly distilled TMS-OTf (0.002 mL, 0.045 mmol) was added

and the reaction allowed to warm to room temperature. After 24 h, the reaction was quenched with 2 drops of NEt_3, filtered and diluted to 20 mL of CH_2Cl_2. The filtrate was washed with 20 mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using flash column chromatography (hexanes:EtOAc, 2:1) to afford **93** (0.017 g, 37%) as a colorless oil/solid: ^{1}H NMR ($CDCl_3$) δ 5. 74 (bs, 1H, N-H), 5.47-5.39 (m, 2H, H4'/H1), 4.99-4.92 (m, 3H, H2'/H3/H3'), 4.38-4.30 (m, 3H, H1'/H4/H2), 4.18-4.08 (m, 2H, H6'/H6'), 3.85-3.73 (m, 3H, H6/H6/CH$_2$-octyl), 3.51-3.41 (m, 3H, H5/H5'/CH$_2$-octyl), 2.13-1.95 (s, 18H, NHAc/OAc), 1.23 (bs, 3H, CH$_2$-octyl), 1.03-0.92 (bs, 9H, CH$_2$-octyl), 0.82 (t, 3H, CH$_3$-octyl). MS (ES, Na^+): m/z (relative intensity) HRMS (M + Na^+) calcd for $C_{47}H_{65}NO_{16}Na$, 842.3; found 842.3 (100).

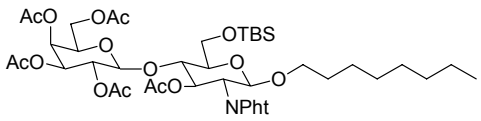
Octyl 4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-3, 6-di-*O*-acetyl-2-deoxy-2-phthalamido-∃-D-glucopyranoside (94).



To a stirred solution of acceptor **87** (0.01 g, 0.018 mmol) and donor **75**[81] (0.05 g, 0.10 mmol) in 6.0 mL of CH_2Cl_2 was added 0.06 g, of 3Å powdered molecular sieves and the mixture heated to reflux. After 1h, the reaction was cooled to -50 °C and $BF_3{\cdot}OEt_2$ (0.0012 mL, 0.010 mmol) was added. After 1.5h, the reaction was quenched with 2 drops of NEt_3, the reaction solution was filtered and the filtrate concentrated. The resulting oil was diluted with 5mL of EtOAc and washed with 5mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate

concentrated. The crude oil was purified using preparative thin layer chromatography (hexanes:EtOAc, 1:1) to afford a partially deprotected disaccharide with complete loss of TBS group and partial loss of OAc groups (0.01 g) as a colorless oil. The resulting crude product was dissolved in 0.5 mL of pyridine and 0.5 mL of Ac_2O. After 20 h, the reaction was diluted with 5.0 mL EtOAc and washed with 5.0 mL of satd. $CuSO_4$, satd. $NaHCO_3$, H_2O, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using preparative thin layer chromatography (hexanes:EtOAc, 1:1) to afford **94** (0.008 g, 55%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.80 (bs, 2H, Pht), 7.76 (s, 2H, Pht), 5.22 (d, 1H, J = 3.7 Hz, H4'), 5.20 (d, 1H, J = 9.0 Hz, H1), 5.17 (dd, 1H, J = 9.8 Hz, H2'), 5.15 (d, 1H, J = 8.5 Hz, H1'), 5.10 (dd, 1H, J = 9.2, 3.2 Hz, H5'), 5.03 (dd, 1H, J = 10.7, 3.8 Hz, H3'), 4.71 (dd, 1H, J = 10.6, 9.1 Hz, H3), 4.33 (dd, 1H, J = 10.5, 8.6 Hz, H2), 4.21 (dd, 1H, J = 12.3, 4.9 Hz, H6'), 4.10 (dd, 1H, J = 12.3, 2.6 Hz, H6'), 3.78 (m, 1H, C$\underline{H}_2$-octyl), 3.74-3.69 (m, 3H, H4/H5/H6), 3.40-3.33 (m, 2H, C$\underline{H}_2$-octyl/H6), 2.15-2.00 (bs, 12H, OAc), 1.91 (bs, 3H, OAc), 1.81 (bs, 3H, OAc), 1.37-1.30 (bs, 12H, C$\underline{H}_2$-octyl), 0.89 (t, 3H, C$\underline{H}_2$-octyl). ^{13}C NMR ($CDCl_3$) δ 171.00, 170.73, 169.73, 169.53, 169.42, 134.36, 131.41, 98.11, 96.44, 74.42, 71.92, 69.95, 67.43, 67.13, 66.77, 66.59, 62.26, 55.36, 31.62, 29.18, 29.04, 25.76, 22.55, 20.88, 20.78, 20.49, 14.00, -0.03. MS (ES, Na^+): m/z (relative intensity) 859.2 (100). HRMS (M + Na^+) calcd for $C_{42}H_{53}NO_{18}Na$, 574.2417; found 574.2415.

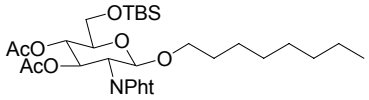
Octyl 4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-3-*O*-acetyl-6-*O*-*t*-butyldimethylsilyl-2-deoxy-2-phthalamido-∃-D-glucopyranoside (95).



To a stirred solution of donor **75**[81] (0.15 g, 0.304 mmol) and acceptor **87** (0.10 g, 0.19 mmol) in 20 mL of CH_2Cl_2 was added 0.25 g 3Å molecular sieves. The reaction was refluxed for 1h and then cooled to -50°C and freshly distilled TMS-OTf (0.0099 mL, 0.045 mmol) was added. After 20 min, the reaction was quenched with 0.1 mL of NEt_3 and filtered. The filtrate was washed with 20 mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using flash column chromatography (hexanes:EtOAc, 2:1) to afford a disaccharide, with partial deprotection of acetates, as a colorless oil/solid (0.10g): MS (ES, Na^+): m/z (relative intensity) 846.2 (100). The partially deprotected glycoside (0.59 g, 0.682 mmol) was dissolved in 10 mL of pyridine and 10 mL of Ac_2O. After 20 h, the reaction was diluted to 50 mL of EtOAc and washed with 50 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude oil was purified using flash column chromatography (hexanes:EtOAc, 2:1) to afford **95** (0.21 g, 36%; 22%, 2 steps) as a colorless oil/solid: ^{1}H NMR ($CDCl_3$) δ 7.79 (bs, 2H, Pht), 7.69 (s, 2H, Pht), 5.67 (dd, 1H, J = 10.7, 9.0 Hz, H3'), 5.31 (d, 1H, J =3.1 Hz, H4'), 5.26 (d, 1H, J = 8.4 Hz, H1), 5.07 (dd, 1H, J = 10.3, 8.0 Hz, H2'), 4.91 (dd, 1H, J = 10.4, 3.5 Hz, H3), 4.69 (d, 1H, J = 7.9 Hz, H1'), 4.13-4.02 (m, 4H, H4/H2/H6/H6), 3.94-3.89 (m, 2H, H6'/H6'), 3.84 (m, 1H, H2), 3.81 (m, 1H, H5'), 3.71 (m, 1H, C$\underline{H}_2$-octyl), 3.47 (m, 1H, Hz, H5), 3.36 (m, 1H, C$\underline{H}_2$-octyl), 2.13-1.86 (s, 18H, NHAc, OAc), 1.67 (bs, 2H, C$\underline{H}_2$-octyl), 1.24-1.00 (bs, 12H, C$\underline{H}_2$-octyl), 0.87 (s, 12H, tBu, C$\underline{H}_3$-octyl), 0.06 (s, 6H, Me).

^{13}C NMR ($CDCl_3$) δ 171.08, 170.30, 170.17, 170.08, 170.05, 168.85, 167.93, 167.93, 167.57, 134.11, 133.94, 131.33, 123.38, 100.32, 97.61, 75.13, 75.08, 71.10, 70.96, 70.49, 69.40, 69.13, 68.67, 66.79, 66.35, 61.02, 60.95, 60.31, 54.99, 31.57, 29.23, 29.04, 25.84, 25.79, 22.50, 20.96, 20.66, 20.57, 20.49, 18.24, 14.11, 13.97, -4.97, -5.33. MS (ES, Na^+): m/z (relative intensity) 930.3 (100). HRMS (M + Na^+) calcd for $C_{38}H_{65}NO_{17}SiNa$, 930.3919; found 930.3926.

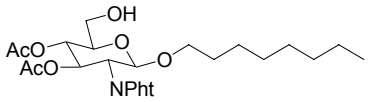
Octyl 3, 4, -di-*O*-acetyl-6-*O*-*t*-butyldimethylsilyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (96).



Compound **87** (0.03 g, 0.06 mmol) was dissolved in Ac_2O (1.00 mL) and pyridine (1.00 mL). After 11 h, the reaction was diluted with 10 mL of EtOAc and washed with 10 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using a short silica gel plug (hexanes:EtOAc, 1:1) to afford **96** (0.034 g, 100%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.83 (m, 2H, Pht), 7.71 (m, 2H, Pht), 5.77 (dd, 1H, J = 10.8, 9.0 Hz, H4), 5.29 (d, 1H, J = 8.4 Hz, H1), 5.05 (m, 1H, H3), 4.24 (dd, 1H, J= 10.7, 8.4 Hz, H2), 3.79 (m, 1H, C$\underline{H}_2$-octyl), 3.72 (m, 2H, H6/H6), 3.67 (m, 1H, H5), 3.40 (m, 1H, C$\underline{H}_2$-octyl), 2.01 (s, 3H, OAc), 1.88 (s, 3H, OAc), 1.23 (bs, 2H, C$\underline{H}_2$-octyl), 1.16-1.01 (bs, 13H, C$\underline{H}_2$-octyl), 0.96-0.79 (s, 12H, tBu, C$\underline{H}_3$-octyl), 0.06 (s, 6H, Me). ^{13}C NMR ($CDCl_3$) δ 170.29, 169.46, 134.82, 133.51, 131.44, 124.15, 122.79, 98.48, 75.28, 74.13, 71.73, 69.16, 62.67, 55.37, 30.21, 29.22, 28.22, 26.34, 25.78, 25.34,

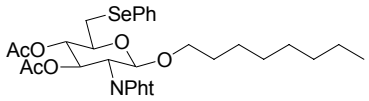
21.26, 21.03, 20.23, 19.99, 13.52, -4.88, -5.82. MS (ES, Na^+): m/z (relative intensity) 642.3 (100). HRMS (M + Na^+) calcd for $C_{32}H_{49}NO_9Na$, 642.3074; found 642.3074.

Octyl 3, 4, *O*-di-*O*-acetyl-2-deoxy-2-phthalimido-β-D-glucopyranoside (97).



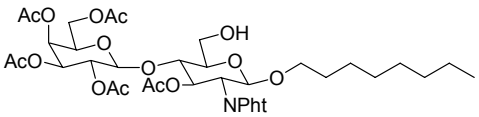
To a stirred 0 °C solution of compound **96** in 1.00 mL of CH_3CN and pyridine (0.30 mL) was added HF·pyridine (0.30 mL). The reaction was allowed to warm to room temperature. After 4.5 h, the reaction was diluted to 5 mL of EtOAc and washed with 5 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparative thin layer chromatography (hexanes:EtOAc, 1:2) to afford **97** (0.025 g, 92%) as a colorless oil: ^1H NMR ($CDCl_3$) δ 7.84 (m, 2H, Pht), 7.71 (m, 2H, Pht), 5.82 (dd, 1H, J = 10.6, 9.2 Hz, H4), 5.36 (d, 1H, J = 8.5 Hz, H1), 5.09 (m, 1H, H3), 4.27 (dd, 1H, J= 10.7, 8.5 Hz, H2), 3.85-3.76 (m, 2H, H5/OH), 3.70-3.62 (m, 3H, C$\underline{H}_2$-octyl/H6/H6), 3.41 (m, 1H, C$\underline{H}_2$-octyl), 2.11 (s, 3H, OAc), 1.92 (s, 3H, OAc), 1.37 (bs, 2H, CH_2-octyl), 1.11-0.99 (bs, 10H, CH_2-octyl), 0.81 (bs, 3H, CH_3). ^{13}C NMR ($CDCl_3$) δ 170.18, 134.30, 131.43, 123.60, 98.20, 74.07, 70.66, 70.13, 69.42, 61.49, 54.84, 31.69, 29.20, 25.81, 22.65, 22.53, 20.75, 20.45, 14.08. MS (ES, Na^+): m/z (relative intensity) 528.2 (100). HRMS (M + Na^+) calcd for $C_{26}H_{35}NO_9Na$, 528.2210; found 528.2224.

Octyl 3, 4, -di-*O*-acetyl-2, 6-dideoxy-6-phenylseleno-2-phthalimido-β-D-glucopyranoside (98).



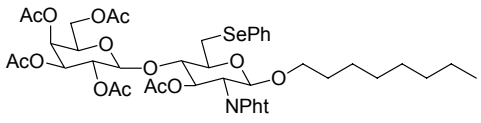
To a stirred -20 °C solution of **97** (0.025 g, 0.049 mmol) in 0.01 mL of CH_2Cl_2 at were added *N*-PSP (0.029 g, 0.098 mmol) and PBu_3 (0.024 mL, 0.098 mmol). The solution was warmed to 0 °C and the temperature maintained. After 24 h, the reaction was diluted with 3 mL of CH_2Cl_2 and washed with satd. $NaHCO_3$, H_2O, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparative thin layer chromatography (hexanes:EtOAc, 2:1) to afford **98** (0.019 g, 60%) as a white powder: ^{1}H NMR ($CDCl_3$) δ 7.90-7.83 (m, 5H, Pht/SePh), 7.79-7.76 (m, 3H, SePh), 7.72 (m, 2H, Pht), 5.75 (dd, 1H, J = 10.6, 9.1 Hz, H4), 5.30 (d, 1H, J = 8.5 Hz, H1), 5.05 (m, 1H, H3), 4.30 (dd, 1H, J= 10.7, 8.6 Hz, H2), 3.87 (m, 1H, H5), 3.73 (m, 1H, C$\underline{H}_2$-octyl), 3.39 (m, 1H, C$\underline{H}_2$-octyl), 3.12-3.08 (dd, 1H, J = 12.9, 8.3 Hz, H6), 3.08-3.04 (m, 1H, H6), 2.00 (s, 3H, OAc), 1.85 (s, 3H, OAc), 1.40 (bs, 2H, C$\underline{H}_2$-octyl), 1.24-0.95 (bs, 10H, C$\underline{H}_2$-octyl), 0.96 (bs, 3H, CH_3). ^{13}C NMR ($CDCl_3$) δ 170.23, 169.74, 134.35, 132.66, 129.14, 127.11, 123.64, 97.94, 73.79, 73.14, 70.73, 69.99, 54.88, 31.66, 29.32, 29.22, 29.13, 25.80, 22.61, 20.77, 20.52, 14.07. MS (ES, Na^+): m/z (relative intensity) 666.1 (100). HRMS (M + Na^+) calcd for $C_{32}H_{39}NO_8Na$, 668.1739; found 668.1740.

Octyl 4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-3-*O*-acetyl-2-deoxy-2-phthalamido-∃-D-glucopyranoside (99).



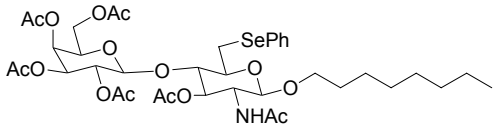
To a stirred 0 °C solution of **95** (0.22 g, 0.24 mmol) in 8.0 mL of CH_3CN and pyridine (1.0 mL) in a Nalgene bottle was added 1.0 mL HF·pyridine. The reaction was allowed to warm to room temperature. After 2.5 h, the reaction was diluted to 25 mL of CH_2Cl_2 and washed with 25 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrated concentrated. The crude oil was purified using a short silica gel plug (EtOAc) to afford **99** (0.177 g, 92%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.80 (bs, 2H, Pht), 7.76 (s, 2H, Pht), 5.47 (m, 1H, H3'), 5.36 (d, J = 8.3 Hz, H1), 5.32 (d, 1H, H4'), 5.28 (m, 2H, H3/H2'), 5.11 (m, 1H, H3), 4.99 (m, 1H, H4), 4.66 (d, 1H, J = 7.7 Hz, H1'), 4.16 (dd, 1H, J = 10.0 Hz, H2), 4.10-3.98 (m, 3H, H6/H6/C$\underline{H}_2$-octyl), 3.94-3.88 (m, 2H, H6'/H6'), 3.78 (m, 2H, H5/H5'), 3.58 (m, 1H, C$\underline{H}_2$-octyl), 3.40 (d, 1H, J = 8.0 Hz, -OH), 2.12-1.89 (s, 18H, NHAc, OAc), 1.67 (bs, 2H, C$\underline{H}_2$-octyl), 1.24-1.12 (m, 10H, C$\underline{H}_2$-octyl), 0.80 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.35, 170.21, 170.11, 169.87, 169.21, 167.97, 134.27, 132.65, 123.56, 100.97, 98.11, 75.61, 74.68, 71.36, 70.97, 70.48, 70.26, 69.21, 66.69, 60.76, 60.50, 55.03, 53.40, 31.59, 29.22, 29.06, 25.75, 22.54, 20.69, 20.64, 20.60, 20.58, 20.52, 14.01, 13.60. MS (ES, Na^+): m/z (relative intensity) 816.3 (100). HRMS (M + Na^+) calcd for $C_{38}H_{50}NO_{17}Na$, 816.3055; found 816.3079.

Octyl 4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)-3-*O*-acetyl-2, 6-dideoxy-6-phenylseleno-2-phthalamido-∃-D-glucopyranoside (100).



To a stirred -20 °C solution of **99** (0.030 g, 0.037 mmol) in 0.10 mL of CH_2Cl_2 was added *N*-PSP (0.022 g, 0.075 mmol) and PBu_3 (0.018 mL, 0.075 mmol). The reaction was warmed to 0 °C and the temperature maintained at 0 °C. After 41 h, the reaction was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of H_2O and satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrated concentrated. The crude oil was purified using preparative thin layer chromatography (hexanes:EtOAc, 2:1) to afford **100** (0.014 g, 40%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.83 (bs, 2H, Pht), 7.71 (m, 2H, Pht), 7.57 (m, 2H, SePh), 7.27 (m, 3H, SePh), 5.71 (dd, 1H, J = 10.6, 8.0 Hz, H2'), 5.33 (d, J = 8.4 Hz, H1), 5.27 (d, 1H, J = 3.4 Hz, H4'), 5.07 (dd, 1H, J = 10.4, 8.4 Hz, H2), 4.81 (dd, 1H, J = 10.4, 3.5 Hz, H3'), 4.46 (d, 1H, J = 8.0 Hz, H1'), 4.20 (dd, 1H, J = 10.6, 8.5 Hz, H3), 4.08 (m, 2H, H6'/H6'), 3.83 (m, 2H, H4/H5'), 3.75 (m, 1H, H5), 3.71 (m, 1H, C$\underline{H}_2$-octyl), 3.43 (d, 1H, J = 12.4, 2.4 Hz, H6), 3.37 (m, 1H, C$\underline{H}_2$-octyl), 3.14 (d, 1H, J = 12.3, 6.7 Hz, H6), 2.14-1.90 (s, 18H, NHAc, OAc), 1.41 (bs, 3H, C$\underline{H}_2$-octyl), 1.24-1.03 (m, 9H, C$\underline{H}_2$-octyl), 0.82 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.35, 170.18, 170.03, 169.84, 168.92, 132.93, 129.24, 127.27, 101.01, 97.79, 80.16, 74.13, 71.06, 70.92, 70.53, 69.91, 69.16, 66.61, 60.78, 55.14, 53.41, 31.64, 29.39, 29.22, 25.79, 22.58, 20.63, 20.57, 20.51, 14.04, 13.62. MS (ES, Na^+): m/z (relative intensity) 956.2 (100). HRMS (M + Na^+) calcd for $C_{44}H_{55}NO_{16}SeNa$, 956.2584; found 956.2607.

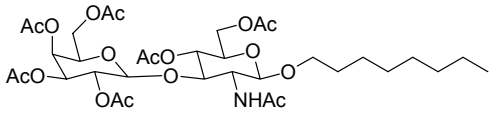
Octyl 2-acetamido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)- 3-*O*-acetyl-6 -phenylseleno-2-deoxy-∃-D-glucopyranoside (101).



To a stirred solution of **100** (0.050 g, 0.053 mmol) in 1 mL of EtOH in a Schlenk tube was added $H_2NNH_2 \cdot H_2O$ (0.23 mL, 4.823 mmol). The reaction was placed under a gentle vacuum, the tube sealed and heated to 100 °C. After 15 h, the reaction was cooled, the tube opened and the reaction mixture concentrated and placed under vacuum for 6 h to afford the free amine as an oil/solid. The product was taken on to the next step without any purification. The crude product was dissolved in 1.0 mL of pyridine and 1.0 mL of Ac_2O. After 17.5 h, the reaction was diluted with 10 mL of EtOAc and washed with 10 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting light yellow oil was purified using flash column chromatography (hexanes:EtOAc, 1:2) to afford **101** (0.040 g, 88%, 2 steps) as a colorless oil/solid: ^{1}H NMR ($CDCl_3$) δ 7.58 (m, 3H, SePh), 7.35 (m, 2H, SePh), 5.60 (d, 1H, J = 9.5 Hz, N<u>H</u>), 5.29 (d, 1H, H4'), 5.04 (dd, 1H, J = 9.0 Hz, H2'), 4.82 (dd, 1H, J = 10.4, 3.3, Hz, H3'), 4.42 (d, 1H, J = 7.5 Hz, H1'), 4.37 (d, 1H, J = 8.0 Hz, H1), 4.08 (m, 2H, H6'/H6'), 4.04 (m, 1H, H5'), 3.81 (m, 1H, H3), 3.78-3.72 (m, 3H, H4/H2/H5), 3.64 (m, 1H, C<u>H</u>$_2$-octyl), 3.38 (m, 2H, H6/H6), 3.14 (m, 1H, C<u>H</u>$_2$-octyl), 2.17 (s, 3H, OAc), 2.13-1.91 (bs, 15H, OAc/NHAc), 1.52 (bs, 3H, C<u>H</u>$_2$-octyl), 1.25 (bs, 9H, C<u>H</u>$_2$-octyl), 0.87 (t, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.67, 170.03, 169.21, 133.48, 132.19, 130.24, 129.19, 128.60, 127.95, 126.67, 100.44, 100.16, 74.77, 73.66, 72.88, 71.19, 70.19, 69.69, 68.45, 67.25, 66.05, 60.87, 53.73, 52.58, 29.39, 25.90, 23.75, 22.73, 21.36, 21.14, 21.02, 20.32, 20.10, 19.99. MS (ES, Na^+): m/z (relative

intensity) 868.3 (100). HRMS (M + Na^+) calcd for $C_{38}H_{55}NO_{17}SeNa$, 868.2635; found 868.2671.

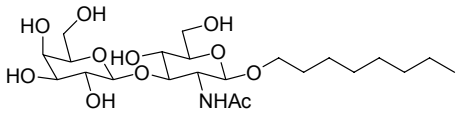
Octyl 2-acetamido-3-*O*-(2,3,4,6-tetra-*O*-acetyl)-∃-D-galactopyranosyl-4, 6-*O*-diacetyl-2-deoxy-∃-D-glucopyranoside (102).



A solution of **82** (0.022 g, 0.026 mmol) in 1.0 mL of H_2O and AcOH (1:1) was heated to reflux. After 2 h, the reaction was cooled and concentrated. The crude product was diluted with 30 mL of EtOAc and washed with 20 mL of satd. $NaHCO_3$ and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified with a short silica gel plug (EtOAc) to afford the diol (0.020 g) as a colorless oil. To a stirred solution of the diol (0.020 g, 0.026 mmol) in 0.5 mL of EtOH in a Schlenk tube was added $H_2NNH_2{\cdot}H_2O$ (0.11 mL, 2.35 mmol). The reaction was placed under a gentle vacuum, the tube sealed and heated to 100 °C. After 41 h, the reaction was cooled, the tube opened and the reaction mixture concentrated and placed under vacuum for 6.5 h to afford the free amino alcohol (0.01 g) as a colorless oil. The product was immediately taken on to the next step without any purification. The crude product (0.0.1 g, 0.022 mmol) was dissolved in 1.0 mL of pyridine and 1.0 mL of Ac_2O. After 18.5 h, the reaction was diluted with 5 mL EtOAc and washed with 5 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting light yellow oil was purified using preparative thin layer chromatography to

afford **102** (0.008 g, 41%, 3 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 5.65 (d, 1H, J = 7.1 Hz, N<u>H</u>), 5.33 (d, 1H, J = 3.3 Hz, H4'), 5.06 (dd, 1H, J = 10.3, 7.9 Hz, H2'), 4.98-4.91 (m, 3H, H1/H3/H3'), 4.56-4.52 (m, 2H, H4/H1'), 4.13-4.06 (m, 4H, H2/H5'/H6'/H6'), 3.87-3.81 (m, 2H, H6/H6), 3.66 (m, 1H, H5), 3.46 (m, 1H, C<u>H</u>$_2$-octyl), 3.13 (m, 1H, C<u>H</u>$_2$-octyl, 2.14 (s, 3H, OAc), 2.09 (s, 3H, OAc), 2.03 (s, 3H, OAc), 2.00 (s, 3H, OAc), 1.96 (s, 3H, NHAc), 1.55 (bs, 3H, C<u>H</u>$_2$-octyl), 1.25 (bs, 9H, C<u>H</u>$_2$-octyl), 0.85 (t, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.73, 170.37, 170.27, 169.50, 168.90, 100.49, 98.96, 71.75, 71.03, 70.62, 70.05, 69.47, 69.11, 66.90, 62.55, 61.04, 60.35, 58.23, 53.37, 31.77, 29.44, 29.28, 25.87, 23.62, 22.60, 20.80, 20.61, 14.03. MS (ES, Na^+): m/z (relative intensity) 770.1 (100). HRMS (M + Na^+) calcd for $C_{34}H_{53}NO_{17}Na$, 770.3229; found 770.3211.

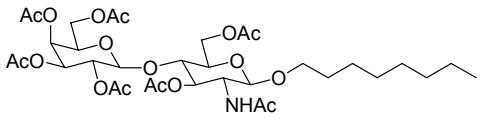
Octyl 2-acetamido-3-*O*-∃-D-galactopyranosyl-2-deoxy-∃-D-glucopyranoside (13b).



To a stirred solution of **102** (0.005 g, 0.0066 mmol) in 0.5 mL of MeOH:THF (1:1) was added 0.5M NaOMe solution (0.0028 mL, 0.0535 mmol). After 4 d, the reaction was quenched with 0.050 g of Dowex 50W H^+ form resin (2.1 meq/mL) and stirred gently for 20 min. The mixture was filtered and the filtrate concentrated. The resulting white powder was purified using a short silica gel plug with $CHCl_3$:MeOH (4:1) to afford **13b** (0.003 g, 100%) as a white powder: ^{1}H NMR (D_2O) δ 4.40 (d, 1H, J = 7.7 Hz, H1), 4.29 (d, 1H, J = 7.7 Hz, H1'), 3.79-3.74 (m, 3H, H2'/H3/H3'), 3.67-3.62 (m,

6H, H4'/H4/H2/H5/H6'/H6'), 3.57-3.43 (m, 2H, H6/H6), 3.41-3.34 (m, 3H, H5/-C$\underline{H}_2$-octyl), 1.90 (s, 3H, NHAc), 1.40 (bs, 3H, C$\underline{H}_2$-octyl), 1.14 (bs, 9H, C$\underline{H}_2$-octyl), 0.72 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR (D_2O) δ 174.48, 103.51, 100.87, 82.49, 75.35, 75.27, 72.49, 70.68, 70.59, 68.75, 68.53, 61.01, 60.77, 54.62, 31.08, 28.55, 28.47, 28.32, 25.07, 22.27, 22.00, 13.37. MS (ES, Na^+): m/z (relative intensity) 518.3 (100). HRMS (M + Na^+) calcd for $C_{22}H_{41}NO_{11}Na$, 518.2577; found 518.2576.

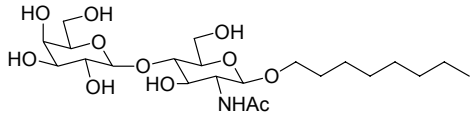
Octyl 2-acetamido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)- 3, 6-*O*-acetyl-2-deoxy-∃-D-glucopyranoside (103).



To a stirred solution of **95** (0.10 g, 0.12 mmol) in 4.0 mL of EtOH in a Schlenk tube was added $H_2NNH_2 \cdot H_2O$ (0.53 mL, 10.4 mmol). The reaction was placed under a gentle vacuum, the tube sealed and heated to 100 °C. After 15 h, the reaction was cooled, the tube opened and the reaction mixture concentrated and placed under vacuum for 6 h to afford the free amino alcohol (0.026 g) as a colorless oil. The product was taken on to the next step without any purification. The crude product was dissolved in 3 mL of pyridine and 3 mL of Ac_2O. After 30 h, the reaction was diluted with 20 mL of EtOAc and washed with 20 mL of satd. $CuSO_4$, H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting yellow oil was purified using flash column chromatography (hexanes:EtOAc, 1:1) to afford **103** (0.06 g, 70%, 2 steps) as a colorless oil/solid: ^{1}H NMR ($CDCl_3$) δ 5.63 (d, 1H, N-$\underline{H}$), 5.35 (d, 1H, H4'), 5.23 (dd, 1H, J = 10.2 Hz, H2'), 5.19 (m, 1H, H3'), 5.04

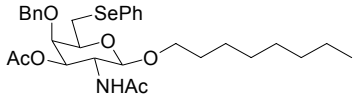
(dd, 1H, J = 10.8, 7.8 Hz, H3), 4.82 (dd, 1H, J = 9.6 Hz, H4), 4.57 (d, 1H, J = 8.3 Hz, H1), 4.53 (dd, 1H, H2), 4.42 (d, 1H, J = 7.4 Hz, H1'), 4.10 (dd, 1H, H6'), 4.00 (m, 1H, H6'), 3.83-3.73 (m, 3H, H6/H6/C$\underline{H}_2$-octyl), 3.64 (m, 1H, H5), 3.57 (m, 1H, Hz, H5'), 3.40 (m, 1H, C$\underline{H}_2$-octyl), 2.07-1.88 (s, 21H, NHAc, OAc), 1.53-1.51 (bs, 3H, C$\underline{H}_2$-octyl), 1.30-1.10 (bs, 9H, C$\underline{H}_2$-octyl), 0.85 (t, 3H, C$\underline{H}_3$-octyl). MS (ES, Na^+): m/z (relative intensity) 770.3 (100). HRMS (M + Na^+) calcd for $C_{32}H_{53}NO_{17}Na$, 770.3211; found 770.3220.

Octyl 2-acetamido-4-*O*-∃-D-galactopyranosyl-2-deoxy-∃-D-glucopyranoside (14b).



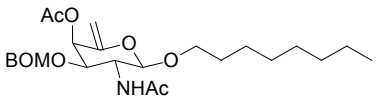
To a stirred solution of **103** (0.055 g, 0.073 mmol) in 3.0 mL of MeOH was added NaOMe powder (0.008 g, 0.148 mmol). After 3 d, the reaction was quenched with 0.10 g of Dowex 50W H^+ form resin (2.1 meq/mL) and stirred gently for 20 min. The mixture was filtered and the filtrate concentrated. The resulting white powder was purified using a short silica gel plug ($CHCl_3$:MeOH, 4:1) to afford **14b** (0.015 g, 42%) as a white powder: ^{1}H NMR (D_2O) δ 4.70-4.60 (m, 2H, H1/H1'), 3.95-3.92 (m, 3H, H2'/H3/H3'), 3.79 (m, 6H, H4'/H4/H2/H5'/H6'/H6'), 3.54-3.45 (m, 5H, H6/H6/H5/-C$\underline{H}_2$-octyl), 2.07 (s, 3H, NHAc), 1.63 (bs, 3H, C$\underline{H}_2$-octyl), 1.32 (bs, 9H, C$\underline{H}_2$-octyl), 0.89 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR (D_2O) δ 133.86, 126.09, 101.71, 75.14, 72.53, 71.75, 70.86, 70.70, 68.86, 66.01, 62.66, 60.98, 56.79, 47.68, 31.10, 28.37, 25.25, 25.07, 22.00, 21.87, 19.95, 13.38. MS (ES, Na^+): m/z (relative intensity) 518.2 (100). HRMS (M + Na^+) calcd for $C_{22}H_{41}NO_{11}Na$, 518.2577; found 518.2582.

Octyl 2-acetamido-3-*O*-acetyl-4-*O*-benzyl-2, 6-dideoxy-6-phenylseleno-∃-D-galactopyranoside (105).



To a stirred 0 °C solution of **42b** (0.145 g, 0.212 mmol) in 3.0 mL of CH_2Cl_2 were added AcBr (0.076 mL, 1.061 mmol) and $BF_3{\cdot}OEt_2$ (0.013 mL, 0.106 mmol). After 3.5 h, the reaction was dissolved in 30 mL of CH_2Cl_2 and washed with 30 mL of satd. $NaHCO_3$, H_2O, satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting oil was purified using flash column chromatography (hexanes:EtOAc, 1:1) to afford **105** (0.09 g, 70%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.48 (m, 2H, PhSe), 7.29 (m, 3H, PhSe), 7.24 (m, 5H, Bn), 5.39 (d, 1H, J = 8.4 Hz, N<u>H</u>), 5.24 (d, 1H, J = 9.2, 2.9 Hz, H4), 4.79 (d, 1H, J = 11.5 Hz, -O-C<u>H</u>$_2$-Ph,), 4.60 (d, 1H, J = 8.3 Hz, H1), 4.49 (d, 1H, J = 11.5 Hz, -O-C<u>H</u>$_2$-Ph), 4.06-4.03 (m, 2H, H3/H2), 3.82 (m, 1H, C<u>H</u>$_2$-octyl), 3.58 (m, 1H, H5), 3.42 (m, 1H, C<u>H</u>$_2$-octyl), 3.18 (dd, 1H, J = 12.6, 6.5 Hz, H6), 2. 94 (dd, 1H, J = 12.6, 7.4 Hz, H6), 2.00 (s, 3H, OAc), 1.93 (s, 3H, NHAc), 1.53 (bs, 2H, C<u>H</u>$_2$-octyl), 1.25 (bs, 10H, C<u>H</u>$_2$-octyl), 0.87 (t, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.75, 170.06, 137.84, 132.66, 129.70, 129.19, 128.36, 128.23, 127.82, 127.15, 100.59, 75.06, 74.50, 74.28, 73.24, 69.46, 53.37, 52.10, 31.78, 29.41, 29.30, 29.24, 27.68, 25.87, 23.46, 22.61, 20.87, 14.05. MS (ES, Na^+): m/z (relative intensity) 628.2 (100). HRMS (M + Na^+) calcd for $C_{37}H_{49}NO_6SeNa$, 628.2153; found 628.2159.

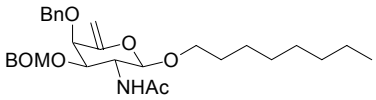
Octyl 2-acetamido-3-*O*-[(benzyloxy)methyl]- 5, 6-dehydro-2, 6-dideoxy-∃-D-glucopyranoside (106a).



To a stirred solution of **42a** (0.100 g, 0.157 mmol) in 21 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.014 g, 0.173 mmol) and $NaIO_4$ (0.050 g, 0.235 mmol). A white precipitate formed during the course of the reaction. After 2.5 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. The H_2O had an additional 30 mL of H_2O added and the aqueous extract was washed 3 times with 30 mL of CH_2Cl_2. The combined organic extracts were washed with 90 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated to afford the selenoxide as a white oil/solid and taken on without any purification (0.100 g): ^{1}H NMR ($CDCl_3$) δ 7.68 (m, 3H, SePh), 7.54 (m, 2H, SePh), 7.33 (m, 5H, ArH of BOM), 5.98 (d, 1H, N-H), 5.28 (d, 1H, J = 3.1 Hz, H4), 4.91 (d, 1H, J = 8.5 Hz, H1), 4.83-4.77 (m, 2H, BOM), 3.64 (m, 1H, H3), 4.55 (m, 1H, H2), 4.32 (m, 1H, H5), 3.94 (m, 1H, H6), 3.80 (m, 1H, H6), 3.57 (m, 2H, CH$_2$-octyl), 2.15 (s, 3H, NHAc), 1.92 (s, 3H, OAc), 1.27 (bs, 12H, CH_2-octyl), 0.86 (bs, 3H, CH_3-octyl). The crude product (0.100 g, 0.153 mmol) was then dissolved in 5 mL of DHP and heated to reflux at 100 °C. After 1.5 h, the reaction was cooled and diluted with 15 mL CH_2Cl_2 and washed with 15 mL of H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using flash columng chromatography (hexanes:EtOAc, 1:2) to afford **106a** (0.042 g, 60%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.59 (m, 3H, ArH of BOM), 7.36 (m, 2H, ArH of BOM), 4.88 (d, 1H, J=7.4

Hz, N-H), 4.80 (m, 1H, H1), 4.00 (m, 2H, H6), 3.63-3.54 (m, 3H, H4/H3/H5), 3.37 (m, 2H, CH_2-octyl), 3.14 (m, 1H, H2), 2.05 (s, 3H, NHAc), 1.76 (s, 3H, OAc), 1.29 (bs, 12H, CH_2-octyl), 0.92 (bs, 3H, CH_3-octyl). ^{13}C NMR ($CDCl_3$) δ 135.50, 134.00, 129.45, 129.17, 120.01, 127.87, 127.62, 97.83, 93.74, 78.09, 63.25, 45.58, 28.83, 28.43, 25.57, 24.15.

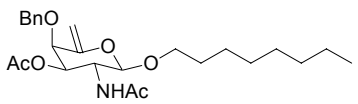
Octyl 4-*O*-benzyl-3-*O*-[(benzyloxy)methyl]- 5, 6-dehydro-2, 6-dideoxy-∃-D-glucopyranoside (106b).



To a stirred solution of **42b** (0.14 g, 0.20 mmol) in 28 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.019 g, 0.225 mmol) and $NaIO_4$ (0.065 g, 0.307 mmol). A white precipitate formed during the course of the reaction. After 1 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. An additional 30 mL of H_2O was added to the filtrate and the aqueous extract was washed 3 times with 30 mL of CH_2Cl_2. The combined organic extracts were washed with 75 mL of NaCl saturated solution and dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 4:1 diastereomeric mixture of selenoxides as a white oil/solid (0.135 g) and taken on without any purification: ^1H NMR ($CDCl_3$) δ 7.62 (m, 3H, SePh), 7.59 (m, 2H, SePh), 7.33 (m, 5H, ArH of BOM), 7.13 (m, 5H, Bn), 6.06 (d, 1H, J = 7.9 Hz, NH), 5.86 (d, 1H, J = 7.5 Hz, NH), 5.35 (d, 1H, J = 2.9 Hz, H4), 5.22 (d, 1H, J = 2.2 Hz, H4), 4.98-4.72, (m, 5H, H1/-O-CH_2-OBn/-O-CH_2-Ph), 4.63 (m, 2H, -O-CH_2-Ph), 4.35 (m, 1H, H3), 3.92 (m, 1H, H2), 3.69-3.43 (m, 5H, H5, H6, H6, CH_2-octyl), 2.14 (s, 3H, NHAc), 1.56 (bs, 2H, CH_2-octyl), 1.27 (bs, 9H,

C$\underline{H}_2$-octyl), 0.84 (bs, 3H, C$\underline{H}_3$-octyl). The crude selenoxides (0.135 g, 0.193 mmol) were dissolved in 10 mL of DHP and heated to reflux at 100 °C. After 2 h, the reaction was cooled and diluted with 25 mL of CH_2Cl_2 and washed with 25 mL of H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using flash column chromatography (hexanes:EtOAc, 1:2) to afford **106b** (0.060 g, 56%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.54 (m, 1H, ArH of BOM), 7.32-7.20 (m, 9H, ArH of BOM, Bn), 5.86 (d, 1H, J=7.2 Hz, N$\underline{H}$), 5.25 (d, 1H, J = 7.6 Hz, H1), 4.86-4.65 (m, 5H, -O-C$\underline{H}_2$-OBn/-O-C$\underline{H}_2$-Ph), 4.51 (m, 2H, H6), 4.59 (dd, 3H, J = 10.3, 3.1 Hz, H3), 4.34 (m, 1H, -O-C$\underline{H}_2$-Ph), 4.11 (m, 1H, H4), 3.92 (m, 1H, C$\underline{H}_2$-octyl), 3.79 (m, 1H, H2), 3.92 (m, 1H, C$\underline{H}_2$-octyl), 1.88 (s, 3H, NHAc), 1.58 (bs, 2H, C$\underline{H}_2$-octyl), 1.25 (bs, 10H, C$\underline{H}_2$-octyl), 0.87 (bs, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.52, 169.32, 152.05, 137.80, 137.61, 133.02, 131.96, 128.98, 128.38, 128.34, 128.27, 127.94, 127.83, 127.76, 127.71, 127.64, 127.50, 127.14, 100.70, 97.73, 93.79, 74.42, 73.76, 73.32, 71.02, 70.01, 69.62, 69.48, 69.40, 50.06, 43.86, 31.79, 29.46, 29.30, 29.25, 25.88, 23.50, 22.62, 14.06. MS (ES, Na^+): m/z (relative intensity) 548.3 (100). HRMS (M + Na^+) calcd for $C_{31}H_{43}NO_6Na$, 548.2988; found 548.2998.

Octyl 3-*O*-acetyl-4-*O*-benzyl-5, 6-dehydro-2, 6-dideoxy-Ξ-D-glucopyranoside (106c).

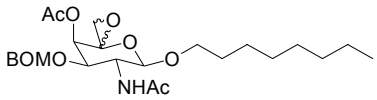


To a stirred solution of **105** (0.090 g, 0.148 mmol) in 21 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.013 g, 0.163 mmol) and $NaIO_4$ (0.047 g, 0.223 mmol). A white

precipitate formed during the course of the reaction. After 1 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. An additional 20 mL of H_2O was added to the filtrate and the aqueous extract was washed 3 times with 20 mL of CH_2Cl_2. The combined organic layers were washed with 50 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 3:1 diastereomeric mixture of selenoxides as a colorless oil/solid (0.070 g) and taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.61 (m, 3H, SePh), 7.52 (m, 2H, SePh), 7.35 (m, 5H, Bn), 6.79 (d, 1H, J = 9.1 Hz, N<u>H</u>), 6.07 (d, 1H, J = 8.6 Hz, N<u>H</u>), 5.16 (d, 1H, J = 7.9, 2.8 Hz, H4), 4.74, (d, 1H, J = 11.7 Hz, -O-C<u>H</u>$_2$-Ph), 4.65 (d, 1H, J = 8.3 Hz, H1), 4.38 (m, 1H, -O-C<u>H</u>$_2$-Ph), 4.12 (m, 1H, H3), 3.88 (dd, 1H, J = 9.6, 6.4 Hz, H2), 3.78-3.71 (m, 2H, H5/C<u>H</u>$_2$-octyl), 3.24 (m, 1H, H6), 2.49 (d, 1H, J = 9.8 Hz, H6), 2.03 (s, 3H, OAc), 1.93 (s, 3H, NHAc), 1.58 (bs, 2H, C<u>H</u>$_2$-octyl), 1.27 (bs, 10H, C<u>H</u>$_2$-octyl), 0.84 (bs, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.81, 170.22, 140.67, 137.40, 131.33, 129.67, 128.55, 128.30, 128.26, 127.90, 126.02, 125.77, 102.05, 100.84, 75.19, 75.08, 73.75, 70.05, 68.77, 55.09, 50.35, 31.80, 29.51, 29.34, 29.26, 25.87, 23.33, 22.61, 20.68, 14.04. The crude selenoxides (0.070 g, 0.112 mmol) were dissolved in 8 of mL DHP and heated to reflux at 100 °C. After 2.5 h, the reaction was cooled and diluted with 10 mL of CH_2Cl_2 and washed with 10 mL of H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using flash column chromatography (hexanes:EtOAc, 1:2, 1% NEt_3) to afford **106c** (0.045 g, 70%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.34-7.25 (m, 5H, Bn), 5.57 (d, 1H, J=8.5 Hz, N<u>H</u>), 5.19 (dd, 1H, J = 10.1, 3.3 Hz, H4), 4.74 (s, 1H, J = 7.4 Hz, -O-C<u>H</u>$_2$-Ph), 4.69 (d, 1H, J = 8.7 Hz, H1), 4.39 (m, 1H, -O-C<u>H</u>$_2$-Ph), 4.28 (m, 1H, H3), 4.08 (m, 1H,

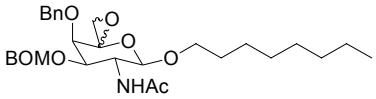
H6), 3.91 (m, 1H, C<u>H</u>$_2$-octyl), 3.49 (m, 1H, C<u>H</u>$_2$-octyl), 3.08 (m, 1H, H2), 2.07 (s, 3H, OAc), 1.94 (s, 3H, NHAc), 1.59 (bs, 2H, C<u>H</u>$_2$-octyl), 1.26 (bs, 10H, C<u>H</u>$_2$-octyl), 0.87 (bs, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.71, 169.97, 151.55, 137.71, 128.26, 127.68, 127.61, 101.64, 100.61, 73.39, 70.16, 69.68, 69.54, 53.37, 51.27, 45.81, 31.78, 29.43, 29.29, 29.22, 25.86, 23.38, 22.60, 20.98, 20.87, 14.03. MS (ES, Na^+): m/z (relative intensity) 470.2 (100). HRMS (M + Na^+) calcd for $C_{31}H_{43}NO_6Na$, 470.2519; found 470.2516.

Octyl 2-acetamido-4-*O*-acetyl-3-*O*-[(benzyloxy)methyl]-2, deoxy-5, 6-epoxy-∃-D-glucopyranoside (107a).



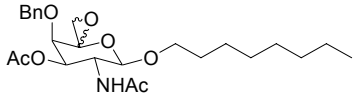
To a stirred 0 °C solution of **106a** (0.030 g, 0.062 mmol) in 1.5mL of CH_2Cl_2 was added DMDO (approximately 15 mL). The reaction was placed in the cold box overnight at 4 °C. After 21 h, the solution was dried with Na_2SO_4, filtered and the filtrate concentrated to afford **107a** (0.03 g, 96%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.62-7.57 (m, 5H, ArH of BOM), 5.74 (bs, 1H, N-<u>H</u>), 5.67 (d, 1H, J = 2.4 Hz, H4), 5.14 (d, 1H, J = 8.0 Hz, H1), 4.63 (s, 2H, -O-C<u>H</u>$_2$-O-Bn), 4.24 (s, 2H, C<u>H</u>$_2$-Ph), 3.98-3.88 (m, 4H, H3/H5/C<u>H</u>$_2$-octyl), 3.68 (dd, 1H, J = 7.9, 4.3 Hz, H2), 3.58-3.52 (m, 2H, H6/H6), 2.07 (s, 3H, OAc), 1.97 (s, 3H, NHAc), 1.92-1.88 (bs, 3H, C<u>H</u>$_2$-octyl), 1.76-1.66 (bs, 9H, C<u>H</u>$_2$-octyl), 1.23 (t, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 140.16, 134.18, 129.97, 129.90, 128.58, 128.29, 127.70, 126.20, 93.38, 88.14, 73.62, 73.46, 68.63, 68.26, 65.37, 59.10, 25.99, 25.49, 25.20, 25.14, 22.90, 20.41, 19.14, -0.05.

Octyl 4-*O*-benzyl-3-*O*-[(benzyloxy)methyl]-2, deoxy-5, 6-epoxy-∃-D-glucopyranoside (107b).



To a stirred 0 °C solution of **106b** (0.035 g, 0.066 mmol) in 1.0 mL of CH_2Cl_2 was added DMDO (approximately 10 mL). The reaction was placed in the cold box overnight at 4 °C. After 21 h, the solution was dried with Na_2SO_4, filtered and the filtrate concentrated to afford **107b** (0.035 g, 97%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.32-7.23 (m, 10H, ArH of BOM/Bn), 4.90-4.32 (m, 14H, N<u>H</u>/H4/H1/O-C<u>H</u>$_2$-O-Bn/C<u>H</u>$_2$-Ph/H3/H5/C<u>H</u>$_2$-octyl/H2/H6/H6), 1.75 (s, 3H, NHAc), 1.60 (bs, 3H, C<u>H</u>$_2$-octyl), 1.24 (bs, 9H, C<u>H</u>$_2$-octyl), 0.87 (t, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 177.99, 133.48, 130.13, 129.79, 129.02, 128.50, 127.87, 127.39, 126.53, 96.27, 94.03, 84.24, 75.09, 69.66, 68.62, 63.03, 58.14, 33.88, 32.73, 31.82, 29.28, 25.73, 25.30, 24.73, 22.86, 14.13.

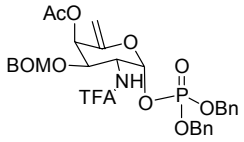
Octyl 3-*O*-acetyl-4-*O*-benzyl-2, deoxy-5, 6-epoxy-∃-D-glucopyranoside (107c).



To a stirred 0 °C solution of **106c** (0.045 g, 0.100 mmol) in 2.0 mL of CH_2Cl_2 was added DMDO (approximately 10 mL). The reaction was placed in the cold box overnight at 4 °C. After 17 h, the solution was dried with Na_2SO_4, filtered and the filtrate concentrated to afford **107c** (0.045 g, 97%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.49-7.32 (m, 5H, Bn), 5.72-5.80 (m, 7H, N<u>H</u>/H4/H1/O-C<u>H</u>$_2$Ph/C<u>H</u>$_2$-Ph), 4.86-4.76 (m, 2H,

H3/H5), 4.07-3.73 (m, 5H, CH_2-octyl/H2/H6/H6), 2.03 (s, 3H, OAc), 1.75 (s, 3H, NHAc), 1.59 (bs, 3H, C$\underline{H}_2$-octyl), 1.24 (bs, 9H, C$\underline{H}_2$-octyl), 0.86 (t, 3H, C$\underline{H}_3$-octyl).

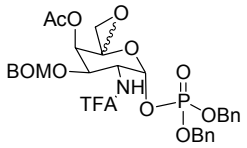
4-*O*-Acetyl, 3-*O*-[(benzyloxy)methyl]-5, 6-dehydro, 2, 6-dideoxy-2-trifluroracetamido-∀-D-galactopyranosyl-1-dibenzyl phosphate (108).



To a stirred solution of **62a** (0.10 g, 0.120 mmol) in 25 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.011 g, 0.132 mmol) and $NaIO_4$ (0.038 g, 0.180 mmol). A white precipitate formed during the course of the reaction. After 3.5 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. The filtrate had 20 mL of H_2O added and the aqueous extract was washed 3 times with 20 mL of CH_2Cl_2. The combined organic extracts were washed with 60 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 3:2 diastereomeric mixture of selenoxides a white oil/solid (0.085 g) and taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.68 (m, 1H, SePh), 7.51 (m, 1H, SePh), 7.47 (m, 3H, SePh), 7.30 (m, 5H, ArH of BOM), 7.27 (m, 10H, Bn/Ph), 5.84 (m, 1H, H1), 5.40 (d, 1H, J = 2.2 Hz, H4), 5.15 (m, 4H, O-C$\underline{H}_2$-Ph/Bn), 5.07 (dd, 1H, J = 9.3, 1.9 Hz, H3), 4.73-4.62 (d, 2H, O-C$\underline{H}_2$-O-Bn/ O-C$\underline{H}_2$-Ph/ ArH of BOM), 4.12 (dd, 1H, J = 11.0, 2.9 Hz, H2), 3.93 (m, 1H, H5), 2.97 (dd, 1H, J = 12.3, 7.8 Hz, H6), 2.79 (dd, 1H, J = 12.3, 4.2 Hz, H6), 2.09 (s, 3H, OAc). ^{13}C NMR ($CDCl_3$) δ 170.72, 170.54, 141.13, 137.34, 137.15, 135.89, 135.80, 135.48, 131.90, 130.22, 129.48, 129.20, 129.14, 129.06, 128.99, 128.92, 128.83, 128.68, 128.62, 128.54, 128.48, 128.36, 128.17, 128.14, 126.45, 126.11, 95.89, 95.80, 93.50, 93.39, 71.05, 70.82,

70.63, 70.56, 70.35, 70.25, 69.49, 68.78, 67.53, 66.90, 55.04, 53.84, 49.54, 21.23, 21.16. ^{19}F NMR δ -75.94. ^{31}P NMR δ -1.20. The crude selenoxides (0.085 g, 0.10 mmol) were dissolved in 3.0 mL of DHP and heated to reflux at 100 °C. After 4.5 h, the reaction was cooled and diluted with 25 mL of CH_2Cl_2 and washed with 25 mL of H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparative thin layer chromatography (hexanes:EtOAc, 1:2) to afford **108** (0.053 g, 67 %, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.34 (m, 5H, ArH of BOM), 7.28 (m, 10H, Bn/Ph), 5.88 (dd, 1H, J = 6.4, 3.1 Hz, H1), 5.73 (d, 1H, J = 3.4 Hz, H4), 5.02 (m, 4H, O-C$\underline{H_2}$-Ph/Bn), 4.76 (s, 2H, O-C$\underline{H_2}$-O-Bn), 4.74 (d, 1H, J = 7.0 Hz, O-C$\underline{H_2}$-O-Bn), 4.70 (d, 1H, J = 7.0 Hz, O-C$\underline{H_2}$-Ph/BOM), 4.67 (m, 1H, H2), 4.55 (m, 2H, H6), 4.07 (dd, 1H, J = 11.0, 3.4 Hz, H3), 2.12 (s, 3H, OAc). ^{13}C NMR ($CDCl_3$) δ 170.16, 157.89, 149.76, 137.09, 135.36, 129.22, 129.17, 129.02, 128.91, 128.83, 128.42, 128.39, 128.29, 128.16, 128.09, 117.07, 114.78, 105.17, 95.58, 93.95, 71.13, 70.36, 70.30, 69.07, 49.52, 21.36. ^{19}F NMR δ 0.48. ^{31}P NMR δ -1.67. MS (ES, Na^+): m/z (relative intensity) 702.1 (100). HRMS (M + Na^+) calcd for $C_{32}H_{33}F_3NO_{10}PNa$, 702.1692; found 702.1703.

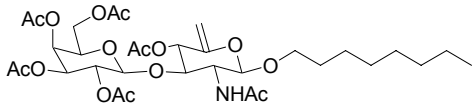
4-*O*-Acetyl, 3-*O*-[(benzyloxy)methyl]-2-deoxy, 5, 6-epoxy-2-trifluroracetamido-∀-D-galactopyranosyl-1-dibenzyl phosphate (109).



To a stirred 0 °C solution of **108** (0.05 g, 0.07 mmol) in 0.5 mL of CH_2Cl_2 was added DMDO (approximately 11 mL). After 7.5 h, an additional 10 mL of DMDO was

added to the reaction mixture. After 23 h, the solution was dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 1:0.7 ratio of epoxides **109** (0.049 g, 85%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.17 (m, 5H, ArH of BOM), 7.06 (m, 10H, Bn/Ph), 6.15 (dd, 1H, H1), 5.98 (dd, 1H, J = 7.5, 3.3 Hz, H1), 5.41 (d, 1H, J = 3.2 Hz, H4), 5.38 (d, 1H, J = 3.3 Hz, H4), 5.04-4.92 (m, 8H, O-C<u>H</u>$_2$-Ph/Bn/ O-C<u>H</u>$_2$-O-Bn/ O-C<u>H</u>$_2$-Ph/ ArH of BOM), 4.67 (dd, 1H, J = 11.9, 6.8 Hz, H2), 4.40 (m, 1H, H3), 2.45 (m, 2H, H6), 2.41 (dd, 2H, J = 8.7, 4.5 Hz, H6), 1.74 (s, 3H, OAc). ^{13}C NMR ($CDCl_3$) δ 168.98, 158.85, 158.56, 137.99, 129.14, 129.01, 128.99, 128.93, 128.90, 128.43, 128.61, 128.56, 128.50, 128.40, 128.31, 128.26, 128.21, 128.12, 128.02, 115.85, 97.01, 95.18, 81.73, 81.44, 73.36, 72.06, 70.68, 70.52, 70.28, 70.21, 68.19, 50.24, 49.50, 25.33, 20.47, 20.40, 20.16.

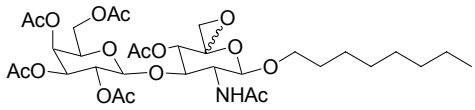
Octyl 2-acetamido-3-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)- 4-*O*-acetyl-5, 6-dehydro-2, 6-dideoxy-∃-D-glucopyranoside (111).



To a stirred solution of **85** (0.010 g, 0.012 mmol) in 1.75 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.001 g, 0.0129 mmol) and $NaIO_4$ (0.004 mg, 0.018 mmol). A white precipitate formed during the course of the reaction. After 2 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. The filtrate had 5 mL of H_2O added and the aqueous extract was washed 3 times with 5 mL of EtOAc. The combined organic extracts were washed with 10 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using flash column

chromatography (hexanes: EtOAc, 1:1) to afford **111** (0.007 g, 87%) as a white oil/solid: ^{1}H NMR ($CDCl_3$) δ 6.03 (d, 1H, J = 9.8 Hz, N-H), 5.88 (d, 1H, J = 8.1 Hz, H1), 5.64 (m, 1H, H3), 5.37 (d, 1H, J = 3.2 Hz, H4'), 5.14 (dd, 1H, J = 10.3, 8.0 Hz, H2'), 5.01 (dd, 1H, J = 10.4, 3.4 Hz, H3'), 4.92 (dd, 2H, J = 3.1 Hz, H6/H6), 4.81 (d, 1H, J = 7.9 Hz, H1'), 4.65 (m, 1H, H4), 4.43-4.40 (m, 3H, J = 6.5 Hz, H5'/H6'/H6'), 3.92 (m, 1H, H2), 3.78 (m, 1H, CH$_2$-octyl), 3.45 (m, 1H, CH$_2$-octyl), 2.10 (s, 3H, OAc), 2.07-1.98 (bs, 15H, OAc/NHAc), 1.55 (bs, 3H, CH$_2$-octyl), 1.19 (bs, 9H, CH$_2$-octyl), 0.85 (t, 3H, CH$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 171.12, 170.37, 170.27, 170.06, 169.54, 169.09, 168.88, 150.88, 145.59, 121.66, 99.74, 95.28, 77.91, 70.98, 70.59, 69.84, 68.96, 68.62, 66.95, 66.42, 60.96, 60.34, 52.72, 31.77, 29.22, 29.13, 25.87, 23.97, 23.30, 22.58, 21.00, 20.93, 20.72, 20.64, 20.60, 20.53, 14.14, 14.05. MS (ES, Na^+): m/z (relative intensity) 710.3 (100). HRMS (M + Na^+) calcd for $C_{32}H_{49}NO_{15}Na$, 710.3000; found 710.2993.

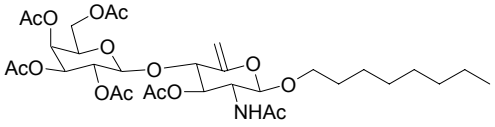
Octyl 2-Acetamido-3-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)- 4-*O*-acetyl-2-deoxy-5, 6-epoxy-∃-D-glucopyranoside (112).



To a stirred 0 °C solution of **111** (0.045 g, 0.065mmol) in 2.0 mL of CH_2Cl_2 was added DMDO (approximately 8 mL). After 13 h, the reaction was dried with Na_2SO_4, filtered and the filtrate was concentrated to afford **112** (0.044 g, 95%) as a colorless oil: ^{1}H NMR (C_6D_6) δ 5.78 (m, 1H, H3'), 5.56 (d, 1H, H4'), 5.50 (dd, 1H, H2'), 5.31 (d, 1H, H1), 5.02 (m, 1H, H3), 4.44 (d, 1H, H1'), 4.30 (m, 1H, H4), 4.18 (m, 1H, H5'), 3.75 (m, 2H, Hz, H6'/H6'), 3.43 (m, 1H, H2), 3.43 (m, 1H, CH$_2$-octyl), 3.13 (m, 1H, CH$_2$-octyl),

2.78 (d, 1H, H6), 2.53 (d, 1H, H6), 2.12-1.69 (bs, 18H, OAc/NHAc), 1.62 (bs, 3H, C$\underline{H}_2$-octyl), 1.25 (bs, 9H, C$\underline{H}_2$-octyl), 0.90 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR (C_6D_6) δ 170.61, 170.44, 170.23, 78.43, 71.66, 69.93, 69.58, 68.09, 67.64, 63.07, 61.58, 33.56, 32.55, 30.44, 30.17, 30.05, 26.65, 26.54, 23.39, 21.20, 21.12, 21.02, 20.64, 20.41, 20.28, 20.21, 14.67, -1.71. MS (ES, Na^+): m/z (relative intensity) HRMS (M + Na^+) calcd for $C_{32}H_{49}NO_{16}Na$, 726.3; found 726.3 (100).

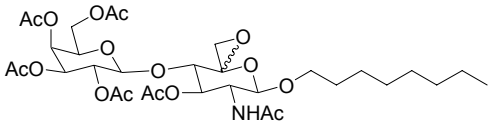
Octyl 2-acetamido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)- 3-*O*-acetyl-5, 6-dehydro-2, 6-dideoxy-∃-D-glucopyranoside (113).



To a stirred solution of **101** (0.04 g, 0.05 mmol) in 7.0 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.005 g, 0.058 mmol) and $NaIO_4$ (0.017 g, 0.080 mmol). A white precipitate formed during the course of the reaction. After 2.5 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. The filtrate had 5.0 mL of H_2O added and the aqueous extract was washed 3 times with 5.0 mL of EtOAc. The combined organic extracts were washed with 10 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated. The resulting mixture of olefin and selenoxides (0.031 g) was taken on without any purification. The crude selenoxides (0.031 g) was dissolved in 3.0 mL of DHP and heated to reflux at 100 °C. After 45 min, the reaction was cooled and diluted with 5.0 mL of CH_2Cl_2 and washed with 5.0 mL of H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate

concentrated. The crude product was purified using flash column chromatography (hexanes:EtOAc, 2:1) to afford **113** (0.012 g, 40%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 6.55 (d, 1H, J = 9.6 Hz, N-H), 5.37 (d, 1H, J = 3.0 Hz, H4'), 5.29 (d, 1H, H1), 5.20 (dd, 1H, J = 8.0 Hz, H2'), 5.06 (dd, 1H, J = 10.5, 3.4 Hz, H3'), 4.92 (s, 1H, H6'), 4.88 (s, 1H, H6'), 4.68 (s, 1H, H6), 4.63 (s, 1H, H6), 4.54 (d, 1H, J = 7.9 Hz, H1'), 4.30 (m, 1H, H4), 4.21 (dd, 1H, J = 4.9 Hz, H3), 4.13 (m, 1H, H5'), 3.89 (m, 1H, H2), 3.75 (m, 1H, CH_2-octyl), 3.36 (m, 1H, CH_2-octyl), 2.17 (s, 3H, OAc), 2.09-1.96 (bs, 15H, OAc/NHAc), 1.53 (bs, 3H, CH_2-octyl), 1.35 (bs, 9H, CH_2-octyl), 0.86 (t, 3H, CH_3-octyl). ^{13}C NMR ($CDCl_3$) δ 171.13, 170.17, 170.09, 169.95, 169.33, 149.46, 103.87, 101.85, 97.76, 73.29, 70.86, 70.28, 69.44, 68.59, 68.05, 66.57, 60.88, 46.82, 31.82, 29.42, 29.32, 29.29, 26.10, 22.88, 22.63, 21.04, 20.85, 20.64, 14.18. MS (ES, Na^+): m/z (relative intensity) 710.3 (100). HRMS (M + Na^+) calcd for $C_{32}H_{49}NO_{15}Na$, 710.3000; found 710.3006.

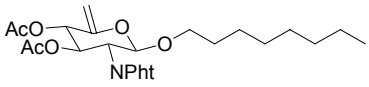
Octyl 2-acetamido-4-*O*-(2,3,4,6-tetra-*O*-acetyl-∃-D-galactopyranosyl)- 3-*O*-acetyl-2-deoxy-5, 6-epoxy-∃-D-glucopyranoside (114).



To a stirred 0 °C solution of **113** (0.011 g, 0.016mmol) in .01 mL of CH_2Cl_2 was added DMDO (approximately 8 mL). After 1 h, the reaction was dried with Na_2SO_4, filtered and the filtrate was concentrated to afford **114** (0.044 g, 95%) as a colorless oil: ^{1}H NMR (C_6D_6) δ 6.37 (d, 1H, J = 9.7 Hz, N-H), 5.60 (m, 1H, H3), 5.49 (d, 1H, J = 3.0 Hz, H4'), 5.27 (d, 1H, J = 8.7 Hz, H1), 5.25 (dd, 1H, J = 10.6, 3.4 Hz, H3'), 4.82 (dd, 1H,

J = 2.8 Hz, H2'), 4.79 (m, 1H, H5'), 4.74 (d, 1H, J = 7.9 Hz, H1'), 4.12 (m, 2H, Hz, H6'/H6'), 3.85 (m, 1H, H4), 3.54 (m, 1H, C$\underline{H}_2$-octyl), 3.36 (m, 1H, H2), 3.18 (m, 1H, C$\underline{H}_2$-octyl), 2.82 (d, 1H, J = 4.7 Hz, H6), 2.43 (d, 1H, J = 4.7 Hz, H6), 2.01-1.61 (bs, 18H, OAc/NHAc), 1.53 (bs, 3H, C$\underline{H}_2$-octyl), 1.28 (bs, 9H, C$\underline{H}_2$-octyl), 0.91 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR (C_6D_6) δ 171.06, 170.41, 170.00, 169.56, 169.22, 103.69, 101.62, 79.06, 74.08, 71.96, 71.49, 71.08, 69.91, 69.73, 67.49, 61.45, 51.45, 49.24, 32.51, 30.11, 30.06, 30.01, 26.64, 23.39, 23.20, 21.04, 20.76, 20.56, 20.48, 20.23, 14.67, -1.73. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{32}H_{49}NO_{16}Na$, 726.3; found 726.3 (100).

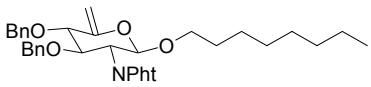
Octyl 3, 4-*O*-di acetyl 5, 6-dehydro-2, 6-dideoxy-2-phthalamido-∃-D-glucopyranoside (115a).



To a stirred solution of **71a** (0.052 g, 0.008 mmol) in 7 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.007 g, 0.088 mmol) and $NaIO_4$ (0.025 g, 0.121 mmol). A white precipitate formed during the course of the reaction. After 2 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. An additional 10 mL of H_2O was added to the filtrate and the aqueous extract was washed 3 times with 15 mL of CH_2Cl_2. The combined organic extracts were washed with 50 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 3:1 diastereomeric mixture of selenoxides as a white oil/solid (0.047 g) and taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.84 (m, 2H, NPht), 7.72 (m, 2H, NPht), 7.54 (m, 5H, SePh), 5.78 (d, 1H, J = 10.3 Hz, H4), 5.65 (d, 1H, J = 10.3 Hz, H4), 5.53 (d, 1H, J = 8.5 Hz, H1), 5.35 (d, 1H, J = 8.5 Hz, H1), 4.97 (m, 1H, H3), 4.28 (m, 1H, H2), 3.89-3.83 (m, 2H, H5/H5), 3.55 (m,

1H, C$\underline{H}_2$-octyl), 3.29 (m, 1H, C$\underline{H}_2$-octyl), 3.09 (m, 1H, H6), 2.93 (m, 1H, H6), 1.98 (s, 3H, OAc), 1.84 (s, 3H, OAc), 1.43 (bs, 2H, C$\underline{H}_2$-octyl), 1.24-0.94 (bs, 9H, C$\underline{H}_2$-octyl), 0.85 (bs, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CHCl_3$) δ 169.94, 168.36, 167.68, 134.91, 134.79, 133.48, 132.78, 131.34, 130.50, 129.22, 126.45, 124.23, 122.77, 98.86, 72.85, 71.70, 70.95, 70.64, 69.75, 69.01, 55.32, 54.19, 31.66, 30.08, 29.11, 28.05, 26.75, 25.75, 22.61, 21.17, 20.89, 20.13, 19.85, 13.50. The crude selenoxides (0.047 g, 0.071 mmol) was dissolved in 3.0 mL of DHP and heated to reflux at 100 °C. After 1.25 h, the reaction was cooled and diluted with 5 mL of CH_2Cl_2 and washed with 5 mL of H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparative thin layer chromatography (hexanes:EtOAc, 2:1) to afford **115a** (0.022 g, 65%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.85 (m, 2H, NPht), 7.32-7.73 (m, 2H, NPht), 5.69 (dd, 1H, J = 10.2, 8.6 Hz, H3), 5.52 (m, 1H, H4), 5.37 (d, 1H, J = 8.3 Hz, H1), 4.88 (m, 1H, H6), 4.64 (m, 1H, H6), 4.42 (dd, 1H, J = 10.2, 8.3 Hz, H2), 3.87 (m, 1H, C$\underline{H}_2$-octyl), 3.46 (m, 1H, C$\underline{H}_2$-octyl), 2.12 (s, 3H, OAc), 1.88 (s, 3H, OAc), 1.44 (bs, 1H, C$\underline{H}_2$-octyl), 1.18-0.95 (bs, 12H, C$\underline{H}_2$-octyl), 0.80 (bs, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 169.94, 169.34, 167.54, 150.75, 134.94, 134.88, 133.58, 131.39, 124.24, 122.89, 99.71, 98.32, 97.55, 71.37, 70.89, 70.46, 70.24, 69.69, 69.19, 55.22, 54.09, 30.20, 29.20, 21.28, 21.02, 20.25, 19.98, 14.53. MS (ES, Na^+): m/z (relative intensity) 510.2 (100). HRMS (M + Na^+) calcd for $C_{26}H_{33}NO_8Na$, 510.2104; found 510.2098.

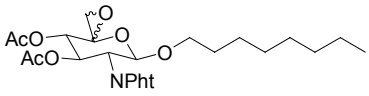
Octyl 3, 4-*O*-di benzyl 5, 6-dehydro-2, 6-dideoxy-2-phthalamido-Ǝ-D-glucopyranoside (115b).



To a stirred solution of **71b** (0.030 g, 0.040 mmol) in 3.5 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.004 mg, 0.044 mmol) and $NaIO_4$ (0.013 g, 0.060 mmol). A white precipitate formed during the course of the reaction. After 4 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. An additional 5 mL of H_2O was added to the filtrate and the aqueous extract was washed 3 times with 10 mL of EtOAc. The combined organic extracts were washed with 30 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 2:1 diastereomeric mixture of selenoxides as a white oil/solid (0.025 g) and taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.71 (m, 2H, NPht), 7.65 (m, 2H, NPht), 7.32 (m, 5H, SePh), 6.90 (m, 5H, Bn), 6.86 (m, 5H, Bn), 5.27 (d, 1H, J = 8.5 Hz, H1), 5.14 (d, 1H, C$\underline{H}_2$-Bn), 5.09 (d, 1H, C$\underline{H}_2$-Bn), 5.01 (d, 1H, C$\underline{H}_2$-Bn), 4.91 (d, 1H, C$\underline{H}_2$-Bn), 4.33 (d, 1H, J = 4.0 Hz, H3), 4.33 (m, 1H, H4), 3.79 (m, 1H, C$\underline{H}_2$-octyl), 3.54 (m, 1H, H2), 3.44 (m, 1H, C$\underline{H}_2$-octyl), 3.39-3.30 (m, 2H, H5/H5), 2.97 (dd, 1H, J = 12.0, 2.9 Hz, H6), 2.65 (m, 1H, H6), 1.26 (bs, 2H, C$\underline{H}_2$-octyl), 1.14-0.90 (bs, 9H, C$\underline{H}_2$-octyl), 0.80 (bs, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CHCl_3$) δ 137.76, 133.78, 132.16, 131.19, 129.78, 129.67, 129.03, 128.64, 128.55, 128.40, 128.31, 128.24, 128.12, 128.07, 127.97, 127.89, 127.46, 127.38, 126.67, 126.21, 125.85, 123.29, 98.41, 98.25, 83.29, 82.68, 77.41, 75.27, 75.04, 73.93, 70.31, 69.85, 69.62, 57.02, 55.98, 32.58, 31.70, 29.08, 25.80, 22.74, 20.99, 14.05. The crude selenoxides (0.025 g, 0.033 mmol) was dissolved in 2.0 mL of DHP and heated to reflux at 100 °C. After 1 h, the reaction was cooled and diluted with 5 mL of CH_2Cl_2 and washed with 5 mL H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was

purified using preparative thin layer chromatography (hexanes:EtOAc, 5:1) to afford **115b** (0.013 g, 68%, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.68 (m, 4H, NPht), 7.40-7.25 (m, 5H, Bn), 6.98 (m, 2H, Bn), 6.86 (m, 3H, Bn), 5.18 (d, 1H, J = 7.9 Hz, H1), 4.87 (bs, 2H, H6/H6), 4.83 (d, 2H, J = 11.4 Hz, C$\underline{H}_2$-Bn), 4.73 (d, 2H, J = 11.4 Hz, C$\underline{H}_2$-Bn), 4.44 (d, 1H, J = 12.2 Hz, H3), 4.24 (dd, 1H, J = 10.4, 8.2 Hz, H2), 4.06 (m, 1H, H4), 3.81 (m, 1H, C$\underline{H}_2$-octyl), 3.40 (m, 1H, C$\underline{H}_2$-octyl), 1.39 (bs, 2H, C$\underline{H}_2$-octyl), 1.16-0.98 (bs, 10H, C$\underline{H}_2$-octyl), 0.80 (bs, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 167.72, 153.72, 137.98, 133.75, 131.63, 128.51, 128.03, 127.95, 127.93, 127.89, 127.33, 123.27, 99.33, 97.19, 80.98, 77.03, 74.27, 73.51, 69.95, 55.69, 54.09, 31.22, 29.20, 24.28, 21.53, 20.35, 14.05. MS (ES, Na^+): m/z (relative intensity) 606.2 (100). HRMS (M + Na^+) calcd for $C_{34}H_{37}NO_6Na$, 606.2832; found 606.2844.

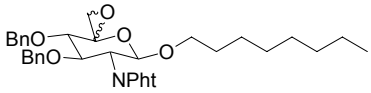
Octyl 3, 4-*O*-di-acetyl-2-deoxy-5, 6-epoxy-2-phthalamido-Ξ-D-glucopyranoside (116a).



To a stirred 0 °C solution of **115a** (0.022 g, 0.045 mmol) in 1.0 mL of CH_2Cl_2 was added DMDO (approximately 10 mL). The reaction was placed in the cold box overnight at 4 °C. After 19 h, the solution was dried with Na_2SO_4, filtered and the filtrate concentrated to afford **116a** (0.021 g, 95%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.62-7.59-7.46 (m, 4H, Pht), 6.22 (d, 1H, H3), 5.67 (d, 1H, J = 8.4 Hz, H1), 5.18 (m, 1H, H4), 3.94 (dd, 1H, J = 8.9, 5.0 Hz, H2), 3.53 (m, 1H, C$\underline{H}_2$-octyl), 3.43 (m, 1H, C$\underline{H}_2$-octyl), 2.82 (m, 1H, H6), 2.44 (m, 1H, H6), 1.75 (s, 3H, OAc), 1.66 (s, 3H, OAc), 1.58 (bs, 3H,

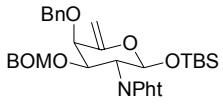
C$\underline{H}_2$-octyl), 1.27-0.99 (bs, 9H, C$\underline{H}_2$-octyl), 0.88 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 169.91, 168.82, 167.52, 133.53, 131.79, 128.11, 123.31, 123.08, 98.26, 79.73, 73.42, 72.11, 71.02, 69.93, 67.54, 55.34, 33.77, 31.15, 29.41, 26.14, 22.87, 20.04, 14.16. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{26}H_{33}NO_9Na$, 526.1; found 526.1 (100).

Octyl 4-*O*-benzyl-2-deoxy-5, 6-epoxy-2-phthalamido-∃-D-glucopyranoside (116b).



To a stirred 0 °C solution of **115b** (0.013 g, 0.022 mmol) in 0.75 mL of CH_2Cl_2 was added DMDO (approximately 5 mL). The reaction was placed in the cold box overnight at 4 °C. After 19 h, the solution was dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 1:1 diastereomeric ratio **116b** (0.011 g, 85%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.59-7.44 (m, 4H, Pht), 7.19-6.93 (m, 10H, Bn), 6.18 (d, 1H, J = 9.3 Hz, H1), 6.12 (d, 1H, J = 9.1 Hz, H1), 5.14 (d, 2H, J = 9.7 Hz, H4/H4), 4.92-4.71 (d, 4H, C$\underline{H}_2$-Bn), 4.60-4.47 (m, 2H, H3/H2), 4.08 (m, 1H, C$\underline{H}_2$-octyl), 3.87 (m, 1H, C$\underline{H}_2$-octyl), 3.44 (m, 1H, H6), 3.33 (m, 1H, H6), 1.58 (bs, 2H, C$\underline{H}_2$-octyl), 1.25-1.03 (bs, 10H, C$\underline{H}_2$-octyl), 0.93 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 133.34, 128.11, 127.23, 123.10, 123.08, 96.54, 81.23, 75.38, 69.93, 56.21, 32.02, 29.41, 26.14, 22.87, 14.16. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{36}H_{41}NO_7Na$, 546.2679; found 622.2 (100).

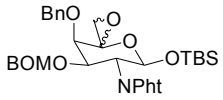
***t*-Butyldimethylsilyl 4-*O*-benzyl-3-*O*-[(benzyloxy)methyl]- 5, 6-dehydro-2, 6-dideoxy-∃-D-glucopyranoside (117).**



To a stirred solution of **67** (0.055 g, 0.071 mmol) in 7 mL of MeOH:H_2O (6:1) were added $NaHCO_3$ (0.007 g, 0.078 mmol) and $NaIO_4$ (0.022 g, 0.106 mmol). A white precipitate formed during the course of the reaction. After 5 h, the reaction was filtered and the filtrate concentrated to leave the H_2O. An additional 10 mL of H_2O was added to the filtrate and the aqueous extract was washed 2 times with 10 mL of CH_2Cl_2. The combined organic extracts were washed with 20 mL of satd. NaCl solution and dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 1:1 diastereomeric mixture of selenoxides as a white oil/solid (0.052 g) and taken on without any purification: ^{1}H NMR ($CDCl_3$) δ 7.82 (m, 2H, NPht), 7.65 (m, 2H, NPht), 7.53 (m, 3H, SePh), 7.40-7.03 (m, 12H, SePh/ ArH of BOM/Bn), 5.52 (d, 1H, H1), 5.38 (d, 1H, H1), 4.99 (d, 1H, -O-C$\underline{H}_2$-OBn), 4.96 (d, 1H, -O-C$\underline{H}_2$-OBn), 4.76-4.61, (m, 11H, -O-C$\underline{H}_2$-OBn/-O-C$\underline{H}_2$-Ph/H4/H4/H3/H3), 4.49 (m, 1H, -O-C$\underline{H}_2$-Ph), 4.29 (m, 2H, -O-C$\underline{H}_2$-Ph), 4.12 (m, 1H, H2), 4.07 (m, 1H, H2), 3.76 (m, 1H, H5), 3.73 (m, 1H, H5), 3.60 (m, 1H, H6), 3.22 (m, 1H, H6), 0.71 (bs, 18H, tBu), 0.11 (s, 3H, tBu), 0.09 (s, 3H, tBu), 0.06 (s, 3H, tBu), 0.03 (s, 3H, tBu). ^{13}C NMR ($CDCl_3$) δ 133.93, 129.60, 128.61, 128.36, 128.31, 128.29, 128.24, 128.22, 127.47, 127.15, 125.60, 94.63, 93.96, 93.79, 76.14, 75.64, 75.25, 74.96, 74.78, 73.12, 69.78, 68.85, 55.93, 54.71, 54.50, 42.09, 25.29, 17.47, -3.95, -4.16, -5.61. The crude selenoxides (0.052 g, 0.066 mmol) were dissolved in 5 mL of DHP and heated to reflux at 100 °C. After 2 h, the reaction was cooled and diluted with 20 mL of EtOAc and washed with 20 mL of H_2O, satd. $NaHCO_3$, and satd. NaCl solutions. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparative thin layer chromatography (hexanes:EtOAc, 3:1) to afford **117** (0.03 g, 75 %, 2 steps) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 8.82 (bs, 2H, NPht),

7.66 (m, 2H, NPht), 7.40-7.20 (m, 8H, ArH of BOM/Bn), 7.06 (m, 2H, Bn), 5.39 (d, 1H, J = 8.0 Hz, H1), 4.89 (d, 1H, -O-C$\underline{H}_2$-Ph), 4.85 (dd, 1H, J = 11.2, 3.1 Hz, H4), 4.76 (d, 1H, J = 10.5 Hz, -O-C$\underline{H}_2$-Ph/C$\underline{H}_2$-Bn), 4.74 (d, 1H, -O-C$\underline{H}_2$-Bn), 4.70 (dd, 1H, J = 11.2, 3.2 Hz, H3), 4.65 (m, 1H, H2), 4.60 (s, 2H, H6/H6), 4.55 (d, 1H, C$\underline{H}_2$-Bn), 1.25 (bs, 9H, tBu), 0.71 (bs, 3H, tBu, 0.65 (bs, 3H, tBu). ^{13}C NMR ($CDCl_3$) δ 171.12, 152.14, 137.97, 137.37, 133.98, 131.65, 128.34, 128.26, 127.88, 127.51, 127.47, 127.20, 102.06, 94.68, 93.46, 75.01, 74.21, 72.40, 69.81, 69.42, 69.34, 60.37, 54.75, 54.09, 25.33, 22.63, 21.03, 17.57, 14.18, -4.28, -5.47. MS (ES, Na^+): m/z (relative intensity) 638.2 (100). HRMS ($M + Na^+$) calcd for $C_{35}H_{41}NO_7Na$, 638.2550; found 638.2562.

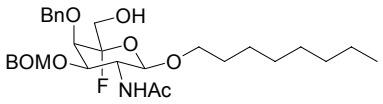
_t_-Butyldimethylsilyl 4-_O_-benzyl-3-_O_-[(benzyloxy)methyl]-2-deoxy-5, 6-epoxy-2-phthalamido-∃-D-galactopyranoside (118).



To a stirred 0 °C solution of **117** (0.03 g, 0.05 mmol) in 1.5 mL of CH_2Cl_2 was added DMDO (approximately 8 mL). After 1 h, the solution was dried with Na_2SO_4, filtered and the filtrate concentrated to afford a 1:1 diastereomeric ratio **118** (0.027 g, 90%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.48 (m, 4H, Pht), 7.31-7.09 (m, 8H, ArH of ArH of BOM/Bn), 6.84 (d, 2H, Bn), 6.20 (d, 1H, J = 8.3 Hz, H1), 5.65 (d, 1H, J = 8.1 Hz, H1), 5.52 (dd, 1H, J = 11.3, 8.3 Hz, H3), 5.33 (dd, 1H, 11.3, 3.0 Hz, H4), 5.16 (dd, 1H, 11.3, 8.1 Hz, H3), 4.88 (d, 1H, -O-C$\underline{H}_2$-Ph), 4.70-4.41 (m, 8H, -O-C$\underline{H}_2$-Ph/C$\underline{H}_2$-Bn/H2/H2), 3.50 (m, 1H, H6), 3.34 (m, 1H, H6), 2.77 (m, 1H, H6), 2.16 (m, 1H, H6), 0.82 (bs, 18H, tBu), 0.21 (bs, 3H, tBu), 0.15 (s, 3H, tBu), 0.09 (s, 3H, tBu), 0.00 (s, 3H,

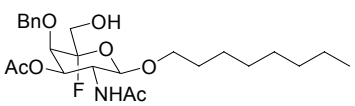
tBu). ^{13}C NMR ($CDCl_3$) δ 139.01, 138.53, 138.29, 134.12, 132.64, 128.94, 128.88, 128.83, 128.76, 128.29, 128.12, 127.98, 127.81, 123.50, 95.09, 94.73, 94.42, 93.63, 79.93, 77.62, 76.57, 75.66, 75.62, 74.70, 74.31, 72.52, 70.19, 70.01, 55.78, 55.11, 52.56, 43.33, 26.01, 25.91, 18.18, -3.42, -3.83, -4.75, -4.92. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{35}H_{37}NO_8Na$, 654.2; found 654.2 (100).

Octyl 4-*O*-benzyl-3-*O*-[(benzyloxy)methyl]-2, deoxy-5-fluoro-∃-D-glucopyranoside (119b).



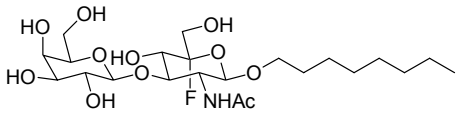
To a stirred -78 °C solution of **107b** (0.035 g, 0.064 mmol) in a Schlenk tube in 1 mL of CH_2Cl_2 was added HF·pyridine (7 drops). After 40 min, the reaction was quenched with 5 drops of NEt_3 and the resulting light yellow solution was concentrated to afford **119b**: ^{1}H NMR ($CDCl_3$) δ 7.37-7.26 (m, 10H, ArH of BOM/Bn), 5.82 (d, 1H, J = 8.3 Hz, N<u>H</u>), 5.10 (s, 1H, O-C<u>H</u>$_2$-O-Bn), 4.75 (d, 1H, J = 7.1 Hz, C<u>H</u>$_2$-Ph), 4.65 (d, 1H, J = 7.0 Hz, C<u>H</u>$_2$-Ph), 4.57-4.48 (m, 5H, H4/H1/H3/H2/ C<u>H</u>$_2$-Ph), 4.42 (d, 1H, J = 10.6 Hz, C<u>H</u>$_2$-Ph), 4.18 (s, 1H, O-C<u>H</u>$_2$-O-Bn), 3.79 (m, 2H, C<u>H</u>$_2$-octyl), 3.53 (m, 2H, H6/H6), 2.90 (bs, 1H, -O<u>H</u>), 1.74 (s, 3H, N<u>H</u>Ac), 1.56 (bs, 3H, C<u>H</u>$_2$-octyl), 1.24 (bs, 9H, C<u>H</u>$_2$-octyl), 0.85 (t, 3H, C<u>H</u>$_3$-octyl). ^{19}F NMR ($CDCl_3$) δ 52.47. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{31}H_{44}NO_7FNa$, 585.0; found 585.0 (100).

Octyl 3-*O*-acetyl-4-*O*-benzyl-2-deoxy-5-fluoro-∃-D-glucopyranoside (119c).



To a stirred -78 °C solution of **107c** (0.021 g, 0.043 mmol) in a Schlenk tube in 1 mL of CH_2Cl_2 was added HF·pyridine (5 drops). After 30 min, the reaction was quenched with 5 drops of NEt_3 and the resulting light yellow solution was concentrated to afford **119c** (0.002 g, 9%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.37-7.26 (m, 5H, Bn), 6.25 (d, 1H, N<u>H</u>), 5.21 (s, 1H, O-C<u>H</u>$_2$Ph), 4.90 (dd, 1H, H4), 4.70 (d, 1H, -O-C<u>H</u>$_2$Ph), 4.57-4.28 (m, 3H, H1/H3/H2), 3.79 (m, 2H, C<u>H</u>$_2$-octyl), 3.27 (m, 2H, H6/H6), 1.99 (s, 1.99, 3H, OAc), 1.74 (s, 3H, N<u>H</u>Ac), 1.56 (bs, 3H, C<u>H</u>$_2$-octyl), 1.24 (bs, 9H, C<u>H</u>$_2$-octyl), 0.85 (t, 3H, C<u>H</u>$_3$-octyl). ^{19}F NMR ($CDCl_3$) δ 52.58. MS (ES, Na^+): m/z (relative intensity) calcd for $C_{25}H_{38}NO_7Na$, 506.2; found 506.2 (100).

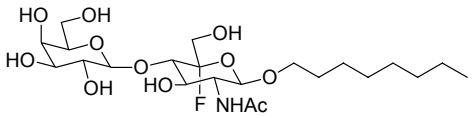
Octyl 2-acetamido-3-*O*-∃-D-galactopyranosyl-2-deoxy-5-fluoro-∃-D-glucopyranoside (13a).



To a -78 °C stirred solution of **112** (0.018 g, 0.025 mmol) in 1.0 mL of CH_2Cl_2 was added HF·pyridine (0.01 mL). After 1.75 h, the reaction was quenched with 0.01 mL of NEt_3 and the resulting light yellow solution was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of H_2O and satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated to afford the (5-F) glycoside (0.030 g) which was taken on without any purification. NH_3 was bubbled through a stirred methanolic solution (2 mL) of the resulting (5-F) glycoside at 0 °C. After 10 min, the flask was sealed and warmed to room temperature. After 1.5 h, the solvent and NH_3 were removed

with a stream of nitrogen. The resulting product was purified using flash column chromatography (EtOAc MeOH, 5:1) to afford **13a** (0.003 g, 25% 2 steps) as a white powder: ^{1}H NMR (D_2O) δ 3.92 (m, 1H, H1), 3.76-3.58 (d, 4H, H1'/H2'/H3/H3'), 3.42-3.28 (m, 6H, H4'/H4/H2/H5'/H6'/H6'), 3.41-3.34 (m, 2H, -C<u>H</u>$_2$-octyl), 2.19-2.06 (m, 2H, H6/H6), 1.86 (s, 3H, NHAc), 1.48 (bs, 3H, C<u>H</u>$_2$-octyl), 1.29 (bs, 9H, C<u>H</u>$_2$-octyl), 0.91 (t, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR (D_2O) δ 174.73, 105.84, 90.69, 77.37, 72.32, 69.80, 61.53, 60.38, 55.56, 46.61, 40.64, 35.13, 29.38, 25.71, 21.58, 10.79. ^{19}F NMR (D_2O) δ 89.6. MS (ES, Na^+): m/z (relative intensity) calcd for; found 536.2 (100). HRMS (M + Na^+) calcd for $C_{22}H_{40}NO_{11}FNa$, 536.2483; found 536.2457.

Octyl 2-acetamido-4-*O*-∃-D-galactopyranosyl-2-deoxy-5-fluoro-∃-D-glucopyranoside (14a).

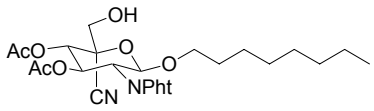


To a -78 °C stirred solution of **114** (0.011 g, 0.015 mmol) in 1.0 mL of CH_2Cl_2 was added HF·pyridine (0.01 mL). After 2 h, the reaction was quenched with 0.01 mL of NEt_3 and the resulting light yellow solution was washed with 5 mL of H_2O and satd. NaCl solution. The organic extract was dried with Na_2SO_4, filtered and the filtrate concentrated to afford the (5-F) glycoside (0.020 g) and taken on without any purification. NH_3 was bubbled through a stirred methanolic solution (2 mL) of the resulting (5-F) glycoside at 0 °C. After 10 min, the flask was sealed and warmed to room temperature. After 1.5 h, the solvent and NH_3 were removed with a stream of nitrogen. The resulting product was purified using flash column chromatography (EtOAc MeOH,

5:1) to afford **14a** (0.003 g, 37% 2 steps) as a white powder: ^{1}H NMR (D_2O) δ 4.12 (d, 1H, J = 7.1 Hz, H1), 3.91 (m, 1H, H1'), 3.73-3.57 (m, 3H, H2'/H3/H3'), 3.44-2.93 (m, 8H, H4'/H4/H2/H5'/H6'/H6'/-C$\underline{H}_2$-octyl), 2.00-1.95 (m, 2H, H6/H6), 2.00 (s, 3H, NHAc), 1.47 (bs, 3H, C$\underline{H}_2$-octyl), 1.32 (bs, 9H, C$\underline{H}_2$-octyl), 0.84 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR (D_2O) δ 173.64, 103.26, 90.68, 75.41, 72.49, 71.01, 69.31, 68.61, 61.94, 61.06, 56.48, 42.26, 31.11, 28.49, 25.05, 22.03, 21.31, 13.42, 10.55.. ^{19}F NMR (D_2O) δ 69.5. MS (ES, Na^+): m/z (relative intensity) calcd for; found 536.2 (100). HRMS (M + Na^+) calcd for $C_{22}H_{40}NO_{11}FNa$, 536.2483; found 536.2485.

Octyl 3, 4-*O*-diacetyl-5-cyano-2-deoxy-2-phthalimido-∃-D-glucopyranoside (124a).

Method (a)



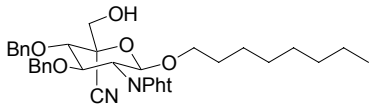
To a stirred 0 °C solution of **116a** (0.014 g, 0.027 mmol) in 1.0 mL of CH_2Cl_2 were added TMS-CN (0.017 mL, 0.139 mmol) and $AlCl_3$ (5.4 mg, 0.040 mmol). The reaction was brought to reflux at 45 °C. After 6.5 h, the reaction was quenched with 1 mL of H_2O and stirred for 5 min. The organic extract was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparatory thin layer chromatography (hexanes:EtOAc, 1:1) to afford **124a** (0.003 g, 21%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.85 (m, 2H, NPht), 7.74 (m, 2H, NPht), 6.13 (d, 1H, H3), 5.97 (d, 1H, J = 8.7 Hz, H1), 5.30 (d, 1H, J = 9.4 Hz, H4), 4.68 (d, 1H, OH), 4.37 (dd, 1H, J = 8.6, 4.7 Hz, H2), 4.18 (m, 1H, H6), 4.04 (d, 1H, J = 10.3 Hz, H6), 3.85 (m, 1H, C$\underline{H}_2$-octyl),

3.75 (m, 1H, C<u>H</u>$_2$-octyl), 2.02 (s, 3H, OAc), 1.95 (s, 3H, OAc), 1.40 (bs, 2H, C<u>H</u>$_2$-octyl), 1.24-0.95 (bs, 10H, C<u>H</u>$_2$-octyl), 0.82 (t, 3H, C<u>H</u>$_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 167.82, 158.83, 134.32, 123.52, 133.65, 93.90, 73.01, 71.86, 70.26, 68.88, 55.10, 53.49, 31.68, 29.84, 25.71, 22.50, 14.00, 0.91. MS (ES, Na^+): m/z (relative intensity) 553.2 (100). HRMS (M + Na^+) calcd for $C_{27}H_{34}N_2O_9Na$, 553.2162; found 553.2168. The resulting product did not stain with DNP.

Method (b)

To a stirred 0 °C solution of **116a** (0.010 g, 0.019 mmol) in 1.0 mL of CH_2Cl_2 were added TMS-CN (0.012 mL, 0.099 mmol) and $BF_3{\cdot}OEt_2$ (0.0036 mL, 0.028 mmol). The reaction was stirred at room temperature. After 6.5 h, the reaction was quenched with 1 mL of H_2O and stirred for 5 min. The organic extract was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparatory thin layer chromatography (hexanes:EtOAc, 1:1) to afford **124a** (0.003 g, 27%) as a colorless oil with identical ^{1}H NMR, ^{13}C NMR and mass spectrum data as identical to those reported for **6.4Aa** prepared by Method (a). The resulting product did not stain with DNP.

Octyl 3, 4-*O*-dibenzyl-5-cyano-2-deoxy-2-phthalimido-∃-D-glucopyranoside (124b).



To a stirred 0 °C solution of **116b** (0.014 g, 0.023 mmol) in 1.0 mL of CH_2Cl_2 were added TMS-CN (0.014 mL, 0.116 mmol) and $AlCl_3$ (4.6 mg, 0.034 mmol). The reaction was brought to reflux at 45 °C. After 6.5 h, the reaction was quenched with 1.0

mL of H_2O and stirred for 5 min. The organic extract was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparatory thin layer chromatography (hexanes:EtOAc, 5:1) to afford **124b** (0.005 g, 35%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 7.65 (m, 4H, NPht), 7.36-7.20 (m, 6H, Bn), 7.09-6.84 (m, 4H, Bn), 6.35 (d, 1H, H4), 5.70 (d, 1H, J = 8.8 Hz, H1), 4.97 (d, 1H, O-C$\underline{H}_2$Ph), 4.77 (d, 2H, -O-C$\underline{H}_2$Ph/H3), 4.65 (d, 1H, O-C$\underline{H}_2$Ph), 4.42 (d, 1H, O-C$\underline{H}_2$Ph), 4.21 (dd, 1H, J = 10.9, 8.8 Hz, H2), 3.96 (m, 1H, H6), 3.81 (d, 1H, H6), 3.64 (m, 1H, C$\underline{H}_2$-octyl), 3.64 (m, 1H, C$\underline{H}_2$-octyl), 1.54 (bs, 2H, C$\underline{H}_2$-octyl), 1.25-1.13 (bs, 10H, C$\underline{H}_2$-octyl), 0.86 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 167.89, 158.13, 137.61, 133.87, 133.65, 128.55, 128.20, 127.82, 127.34, 123.23, 100.20, 94.58, 81.42, 75.02, 74.95, 73.03, 69.88, 56.14, 31.62, 29.30, 29.04, 25.71, 22.55, 14.03, 0.01. MS (ES, Na^+): m/z (relative intensity) 649.2 (100). HRMS (M + Na^+) calcd for $C_{37}H_{42}N_2O_7Na$, 649.2890; found 649.2885. The resulting product did not stain with DNP.

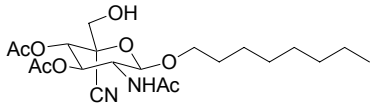
Method (b)

To a stirred 0 °C solution of **116b** (0.010 g, 0.016 mmol) in 1.0 mL of CH_2Cl_2 were added TMS-CN (0.010 mL, 0.083 mmol) and $BF_3{\cdot}OEt_2$ (0.0034 mL, 0.024 mmol). The reaction was stirred at room temperature. After 6.5 h, the reaction was quenched with 1 mL of H_2O and stirred for 5 min. The organic extract was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparatory thin layer chromatography (hexanes:EtOAc, 5:1) to afford **124b** (0.001 g, 10%) as a colorless oil

with identical ^{1}H NMR, ^{13}C NMR and mass spectrum data as identical to those reported for **6.4Ab** prepared by Method (a). The resulting product did not stain with DNP.

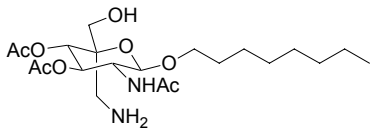
Octyl 3, 4-*O*-diacetyl-2-acetamido-5-cyano-2-deoxy-∃-D-glucopyranoside (124c).

Method (a)



To a stirred 0 °C solution of **123**[8] (0.037 g, 0.089 mmol) in 2.0 mL of CH_2Cl_2 were added TMS-CN (0.050 mL, 0.445 mmol) and $AlCl_3$ (17 mg, 0.133 mmol). The reaction was brought to reflux at 45 °C. After 15.5 h, the reaction was quenched with 5 mL of H_2O and stirred for 5 min. The organic extract was diluted to 5 mL of CH_2Cl_2 and washed with 5 mL of satd. NaCl solution, dried with Na_2SO_4, filtered and the filtrate concentrated. The crude product was purified using preparatory thin layer chromatography (hexanes:EtOAc, 1:1) to afford **124c** (0.013 g, 33%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 6.77 (d, 1H, J = 9.4 Hz, N-H), 4.94 (d, 1H, H3), 4.79-4.65 (d, 3H, H1/H4/OH), 4.33 (m, 1H, H2), 4.18 (m, 1H, H6), 3.94 (d, 1H, H6), 3.23 (m, 2H, C$\underline{H}_2$-octyl), 2.20 (s, 3H, OAc), 2.12 (s, 3H, OAc), 1.96 (s, 3H, NAc), 1.63 (bs, 2H, C$\underline{H}_2$-octyl), 1.26 (bs, 10H, C$\underline{H}_2$-octyl), 0.87 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 170.46, 170.15, 100.45, 69.70, 67.90, 65.85, 64.32, 50.99, 46.63, 31.77, 29.46, 25.88, 22.80, 21.01, 14.09. MS (ES, Na^+): m/z (relative intensity) calcd for; found 465.2 (100). HRMS (M + Na^+) calcd for $C_{21}H_{34}N_2O_8Na$, 465.2213; found 465.2204. The resulting product did not stain with DNP.

Octyl 3, 4-*O*-diacetyl-2-acetamido-5-methyleneamino-2-deoxy-∃-D-glucopyranoside (126).



To a solution of **124c** (0.010 g, 0.022 mmol) in 10 mL of MeOH was added PtO_2 (50 mg, 0.180 mmol). The mixture was hydrogenated at 40 PSI. After 25 h, the reaction mixture was filtered through Celite and concentrated. The crude product purified using flash column chromatography (hexanes:EtOAc, 2:1) to afford **126** (0.09 g, 90%) as a colorless oil: ^{1}H NMR ($CDCl_3$) δ 5.99 (d, 1H, H3), 5.73 (d, 1H, J = 9.1 Hz, N-H), 5.22 (m, 1H, H4), 4.85 (d, 1H, J = 4.0 Hz, OH), 4.23-4.17 (m, 2H, H1/H2/CH_2), 3.90 (m, 2H, H5/CH_2), 3.65 (d, 1H, C$\underline{H}_2$-octyl/NH_2), 3.61-3.49 (m, 3H, H6/H6/C$\underline{H}_2$-octyl), 2.12 (s, 3H, OAc), 2.06 (s, 3H, OAc), 1.94 (s, 3H, NAc), 1.59 (bs, 2H, C$\underline{H}_2$-octyl), 1.26 (bs, 10H, C$\underline{H}_2$-octyl), 0.86 (t, 3H, C$\underline{H}_3$-octyl). ^{13}C NMR ($CDCl_3$) δ 172.43, 170.13, 166.46, 98.50, 79.21, 73.24, 70.48, 69.34, 66.58, 52.35, 40.64, 31.68, 29.61, 26.17, 22.73, 21.12, 14.00. MS (ES, Na^+): m/z (relative intensity) calcd for; found 469.2 (100). HRMS (M + Na^+) calcd for $C_{21}H_{38}N_2O_8Na$, 469.2526; found 469.2514.

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