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Site-Selective Acylation of Pyranosides with Oligopeptide Catalysts

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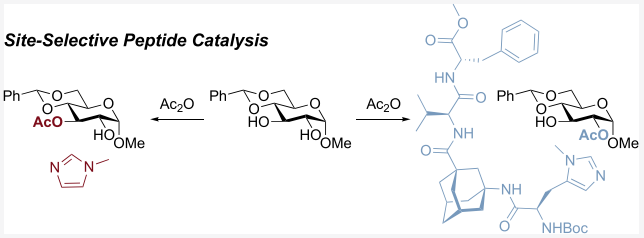
ABSTRACT: Herein, we report the oligopeptide-catalyzed site-selective acylation of partially protected monosaccharides. We identified catalysts that invert site-selectivity compared to *N*-methylimidazole, which was used to determine the intrinsic reactivity, for 4,6-*O*-protected glucopyranosides (*trans*-diols) as well as 4,6-*O*-protected mannopyranosides (*cis*-diols). The reaction yields up to 81% of the inherently unfavored 2-*O*-acetylated products with selectivities up to 15:1 using mild reaction conditions. We also determined the influence of protecting groups on the reaction and demonstrate that our protocol is suitable for one-pot reactions with multiple consecutive protection steps.



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INTRODUCTION

Carbohydrates are omnipresent as oligosaccharides and glycoconjugates and are vital to a variety of biological processes.[1] Among other things, nature uses carbohydrates to encode information.[2] Synthesizing these complex compounds is a challenging task as multiple monosaccharides have to be selectively linked to each other.[3] Consequently, much effort has been devoted to the development of selective glycosylation reactions, for which temporary site-selective functionalization (e.g., protection) of the monosaccharide building blocks is often indispensable.[4] The hydroxy groups in monosaccharides show reactivities that are depending on various influences, some important ones being the intramolecular hydrogen bonding network, steric effects, the protecting groups already installed, and the reaction conditions.[5] Hence, a lot of different methods were discovered to change the initial reactivity and selectively to address specific hydroxy groups.[6] One way to accomplish these protections is through the use of catalysts that can site-selectively distinguish between the different hydroxy groups by using metal-based catalysts,[7] organocatalysts,[6a,8] and enzymes.[4c,9] Given the importance of carbohydrate recognition in biological systems, oligopeptides are of special interest among the class of organocatalysts.[8g,10] Pioneering studies in the site-selective acylation of carbohydrates using oligopeptide catalysts have been performed by the Miller group in 2003, screening 150 different oligopeptide catalysts bearing a π-methyl histidine (Pmh) moiety for their ability to site-selectively acetylate an amino sugar derivative, and compared the results to *N*-methylimidazole (NMI), the reference catalyst.[11] Most catalysts enhanced the selectivity for the acetylation at the intrinsically favored 3-hydroxy group, and the best catalyst afforded up to 97% of the corresponding monoacetylated product. However, some of the catalysts were able to change the selectivity and shifted the distribution of the products toward the typically highly unfavored 4-*O*-acetylation. The best catalyst "favoring" 4-OH was able to give an almost 1:1 ratio of the monoacetylated products.[11] Kirsch's group screened a library of oligopeptide catalysts bearing a 4-(dimethylamino)pyridine (DMAP) moiety, achieving site-selective acylation for different methyl 4,6-*O*-protected monosaccharides.[12] An excess of triethylamine was employed, which, however, also leads to site-selective acylation in some cases.[13] Recently, we reported the application of photoisomerizable azobenzene-based oligopeptides that allowed switching the site selectivity in the acetylation of carbohydrate diols and the natural product quercetin through irradiation.[14]

Here, we report the site-selective acylation of carbohydrates using oligopeptide catalysts (Figure 1) bearing Pmh as the catalytically active site and an adamantane moiety in the backbone to improve solubility in organic solvents[15] and to provide a dynamic binding pocket for the substrates.[16] These

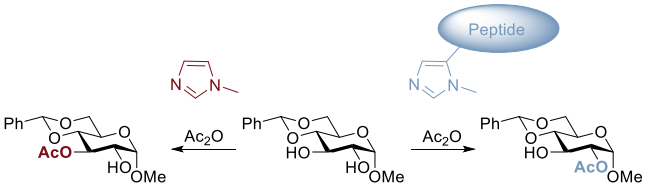

Figure 1. Site-selective acetylation of methyl 4,6-*O*-benzylidene-α-D-glucopyranoside using peptide catalysts.

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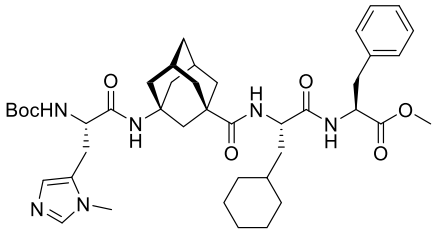
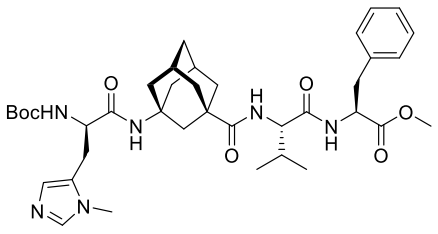
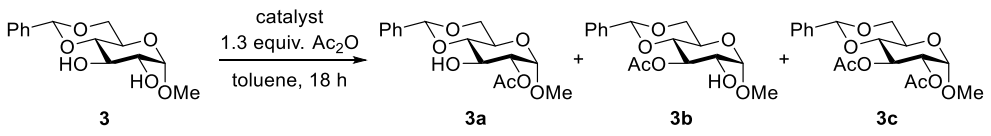
Table 1. Acetylation of Methyl 4,6-*O*-Benzylidene-α-D-glucopyranoside 3 with NMI and Oligopeptide Catalysts 1 and 2







Entry	Catalyst	3a [%]	3b [%]	3c [%]	*C* (%)	Selectivity (%)[d]
1	none	-	-	-	-	-
2	NMI[a]	20	62	5	87	23
3	1[b]	55	37	8	>95	55
4	2[b]	70	19	3	92	76
5	2[c]	81	17	2	>95	82

[a]10 mol % cat., rt, [3] = 0.01 mol L^{-1}. [b]5 mol % cat., rt, [3] = 0.01 mol L^{-1}. [c]Conditions obtained by DoE: 5 mol % cat., 0 °C, [3] = 0.005 mol L^{-1}. [d]x = 3a/(3a + 3b + 3c) × 100; product ratios and conversion determined via ^{1}H NMR.

catalysts permit enantioselective acetylations of cyclic diols with high yield and selectivity.[15,17] We now developed this class of oligopeptides into site-selective catalysts for the acylation of monosaccharides that are building blocks for subsequent glycosylation reactions. Furthermore, we investigated the substrate−catalyst interactions by changing the 4,6-*O*-acetal protecting groups and by modifying the anomeric center.

RESULTS AND DISCUSSION

We commenced our investigation using methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (**3**), which is commercially available and has already been investigated as a substrate in site-selective acylation reactions.[8f,9,12a,13,18] First, we synthesized the monoacetylated derivatives **3a** and **3b** as well as the diacetylated product **3c**, using DMAP as the catalyst. We chose ^{1}H NMR analysis as our analytical method of choice as it allowed the unambiguous differentiation between all products as well as the starting material, and the product ratios and conversions could be readily determined (see the Supporting Information for details).

We tested the peptide catalysts using conditions similar to those of Griswold and Miller[11] and used NMI as a reference catalyst to gauge the intrinsic reactivity. Without catalyst, the substrates showed no reactivity under these conditions. NMI favors formation of **3b** with a ratio of 20:62:5 (**3a**:**b**:**c**, Table 1, entry 2). Screening of different peptide catalysts (see the Supporting Information for the complete catalyst library) showed that most of them preferentially led to the formation of 2-*O*-acetylated product **3a**. Catalyst **1**, for example, which has proven excellent for the acylation of 1,2-alkane diols,[15,17a,b] achieved an overall yield higher than 95% with a selectivity of 55% for **3a** (Table 1, entry 3). Of all tested catalysts, tetrapeptide **2** with a selectivity of 76% performed best (Table 1, entry 4; 66% of **3a** were isolated performing the reaction on a 5.0 mmol scale). To optimize the reaction conditions, a design of experiments (DoE) study was carried out (see the Supporting Information for details).[19] We used a Custom Design approach using JMP and chose five different variables for optimization: Concentration (0.1−0.005 mmol), catalyst loading (0.1−10%), amount of acetic anhydride (1.0−10 equiv), reaction time (1−18 h) and temperature (−20 to +20 °C). These starting conditions for DoE optimization contained a total of 27 experiments in random order for optimization of all variables, which is much less than would be needed in a typical step-by-step optimization. After performing the reactions (plus repeating an additional five reactions for a higher accuracy) we were able to generate a prediction profiler (Figure S13), which was used to determine the best reaction conditions. Using these conditions, we could further increase the selectivity to 82% (Table 1, entry 5). These results are as good as the best currently available in the literature (see Table S3 for comparisons) and use mild reactions conditions, making the reaction interesting for multi-step sequences.

To investigate the influence of the 4,6-*O*-protecting group and the anomeric center on the pyranoside, we performed experiments with other monosaccharides as well. Using methylidene instead of benzylidene as the protecting group,

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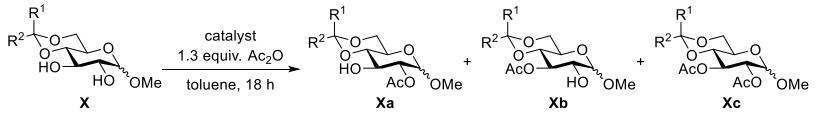
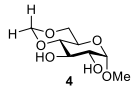
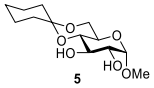
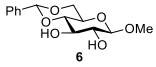
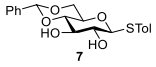
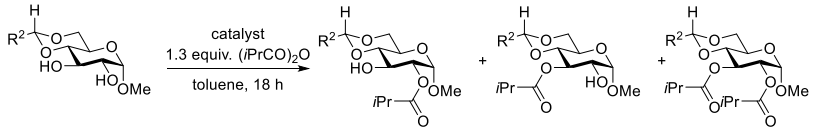
Table 2. Acetylation of 4,6-*O*-Protected Glucopyranoside Derivatives 4−7 with NMI and Tetrapeptide Catalyst 2

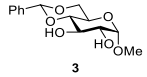
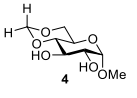


Entry	Starting Material	Catalyst	Xa [%]	Xb [%]	Xc [%]	*C* (%)	Selectivity (%)[d]
1		NMI[a]	23	33	2	58	40
2		**2**[b]	76	20	4	>95	76
3		**2**[c]	74	13	3	90	82
4		NMI[a]	18	18	-	36	50
5		**2**[b]	55	9	-	64	86
6		**2**[c]	59	10	-	69	86
7		NMI[a]	6	18	8	32	19
8		**2**[b]	21	29	25	75	28
9		**2**[c]	6	8	1	15	40
10		NMI[a]	22	36	4	62	35
11		**2**[b]	53	38	9	>95	53
12		**2**[c]	58	37	5	>95	58

[a]10 mol % cat., rt, [*X*] = 0.01 mol L^{-1}. [b]5 mol % cat., rt, [*X*] = 0.01 mol L^{-1}. [c]Conditions obtained by DoE: 5 mol % cat., 0 °C, [*X*] = 0.005 mol L^{-1}. [d]x = ***X*a**/(***X*a** + ***X*b** + ***X*c**) × 100; product ratios and conversion determined via ^{1}H NMR.

Table 3. Acylation of 4,6-*O*-Protected Glucopyranoside Derivatives 3 and 4 Using Isobutyric Anhydride



Entry	Starting Material	Catalyst	Xa [%]	Xb [%]	Xc [%]	*C* (%)	Selectivity (%)[d]
1		NMI[a]	22	47	2	71	31
2		**2**[b]	76	11	2	89	85
3		**2**[c]	76	10	6	92	83
4		NMI[a]	26	25	3	54	48
5		**2**[b]	79	8	4	91	87
6		**2**[c]	68	7	6	81	84

[a]10 mol % cat., rt, *c* = 0.01 mol L^{-1}. [b]5 mol % cat., rt, *c* = 0.01 mol L^{-1}. [c]Conditions obtained by DoE: 5 mol % cat., 0 °C, 0.005 mol L^{-1}. [d]x = ***X*a**/(***X*a** + ***X*b** + ***X*c**) × 100; product ratios and conversion determined via ^{1}H NMR.

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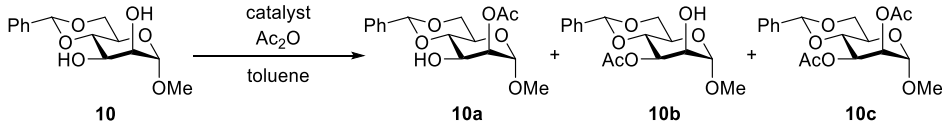
Table 4. Acetylation of Methyl 4,6-*O*-Benzylidene-α-D-mannopyranoside 10 with NMI and Tetrapeptide Catalysts 1 and 2



Entry	Catalyst	10a [%]	10b [%]	10c [%]	*C* (%)	Selectivity (%)[d]
1	none	-	-	-	-	-
2	NMI[a]	4	55	14	73	5
3	2[b]	25	43	15	83	30
4	1[b]	57	5	38	>95	57
5	1[c]	65	5	5	75	87

[a]10 mol % cat., 1.3 equiv Ac_2O, 18 h, rt, c = 0.01 mol L^{-1}. [b]5 mol % cat., 1.3 equiv Ac_2O, 18 h, rt, c = 0.01 mol L^{-1}. [c]Conditions obtained by DoE: 10 mol % cat., 1.0 equiv Ac_2O, 2 h, 20 °C, 0.005 mol L^{-1}. [d]x = **10a**/(**10a** + **10b** + **10c**) × 100; product ratios and conversion determined via ^1H NMR.

catalyst **2** was still able to overcome the reactivity and selectivity of NMI (Table 2, entry 1), giving 76% selectivity for the desired 2-*O*-acetylated product **4a** (Table 2, entry 2). Applying the reaction conditions given by DoE, the yield slightly decreased but the selectivity improved up to 82% (Table 2, entry 3). Even better selectivity of 86% was observed with cyclohexylidene-protected derivative **5**. No diacetylated product **5c** formed, but the overall conversion was significantly lower (64%; Table 2, entry 5). Note that with **5** as starting material, NMI no longer favored the formation of 3-*O*-acetylated product **5b** but rather gave both monoacetylated products in a 1:1 ratio with only 36% yield (Table 2, entry 4). The outcome of the reaction was just slightly different using DoE conditions (Table 2, entry 6). With β-anomer **6**, NMI showed similar selectivity to the α-anomer, favoring **6b** over **6a**; however, an appreciable amount of diacetylated product **6c** formed and the overall conversion was low (Table 2, entry 7). Catalyst **2** was able to raise the overall conversion to 75% but still a large amount of diacetylated product **6c** ensued. Interestingly, the selectivity collapses (Table 2, entry 8), indicating that the anomeric configuration is important. This must be due to changes in the interactions between the substrate and the catalyst, which might be owing, in part, to changes in the diol intramolecular hydrogen bonding patterns (H-bonding from 2-OH to 1-OMe would be expected to be stronger for the α-anomer). We also tested β-thioglucopyranoside derivative **7**, which may be an interesting precursor in glycosidic bond formation.[20] We again observed a lower selectivity of 53% compared to the α-derivatives (Table 2, entry 11). Compared to NMI (Table 2, entry 10), the selectivity was again inverted, and the overall conversion increased. Applying the conditions obtained by DoE, we could slightly increase the selectivity to 58% and decrease the amount of diacetylated product **7c** (Table 2, entry 12).

We also investigated the influence of the acylation reagent employing isobutyric anhydride[21] [(*i*PrCO)$_2$O] and carbohydrate derivatives **3** and **4** as starting materials; these starting materials were investigated by Xiao et al. as well.[8f] When **3** was used, we achieved good reactivity and a selectivity of 85% for 2-*O*-acetylated product **8a** (Table 3, entry 2). The selectivity further increased up to 87% using **4** as the starting material (Table 3, entry 5). For both derivatives, the selectivity increased compared to acetic anhydride, the intrinsic reactivity of NMI was inverted and the overall conversion was high, although less reactive isobutyric anhydride was used.

To explore whether our peptide-based catalyst would invert NMI selectivity with other sugars, we also employed methyl 4,6-*O*-benzylidene-α-D-mannopyranoside (**10**) as the substrate. NMI again favored the formation of 3-*O*-acetylated product with an even higher selectivity and overall good conversion of 73% but also accompanied by an appreciable amount of diacetylated product **10c** (Table 4, entry 2). Peptide catalyst **2** catalyzed the acetylation of **10** with an overall good conversion of 83%. The intrinsic reactivity was not inverted but slightly altered toward the 2-*O*-acetylated product, yielding a selectivity of 30% (Table 4, entry 3). With catalyst **1**, we observed high reactivity and good selectivity of 57%, but also a lot of diacetylated product **10c** formed (Table 4, entry 4). To decrease the amount of diacetylated product as well as to further increase the selectivity, we employed a DoE strategy.[19c] As a result, the selectivity increased up to 87% (Table 4, entry 5). The dramatic reduction in the diacetylated product was accompanied by a slight increase in the **10a**:**b** ratio from 11:1 to 13:1. This was the best ratio of mono-acetylated products we had observed at this stage; and, to the best of our knowledge, the best results for a nonenzymatic selective acetylation at the 2-OH-group of methyl 4,6-*O*-benzylidene-α-D-mannopyranoside **10** known (see Table S4 for comparison). One might have expected that **10b** would be acetylated more rapidly than **10a** as it bears the same 2-OH as the starting diol; the large reduction in **10c** might have been expected to have led to an increase in the amount of **10b** versus **10a**. Even allowing for the greater concentration of **10a**, the improved selectivity seems to imply that the diacetylation process exhibits quite a different selectivity for 2-OH versus 3-OH than in the reaction with diol **10**. Performing the reaction on a larger scale (1.0 mmol), we were able to isolate 68% of the

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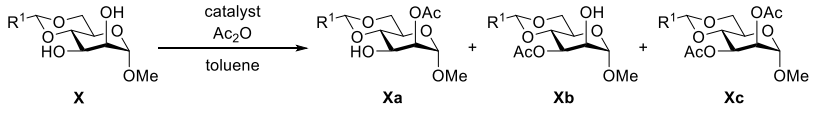
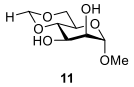
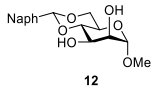
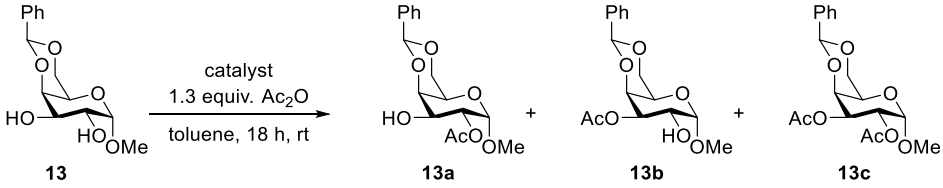
Table 5. Acetylation of 4,6-*O*-Protected Mannopyranoside Derivatives 11 and 12 with NMI and Tetrapeptide Catalyst 1



Entry	Starting Material	Catalyst	Xa [%]	Xb [%]	Xc [%]	*C* (%)	Selectivity (%)[d]
1	 11	NMI[a]	7	33	6	46	15
2		**1**[b]	68	11	21	>95	68
3		**1**[c]	40	12	3	55	73
4	 12	NMI[a]	3	16	3	22	14
5		**1**[b]	62	4	22	88	70
6		**1**[c]	59	4	6	69	86

[a]10 mol % cat., 1.3 equiv Ac_2O, 18 h, rt, c = 0.01 mol L^{-1}. [b]5 mol % cat., 1.3 equiv Ac_2O, 18 h, rt, c = 0.01 mol L^{-1}. [c]Conditions obtained by DoE: 10 mol % cat., 1.0 equiv Ac_2O, 2 h, 20 °C, 0.005 mol L^{-1}. [d]x = **Xa**/(**Xa** + **Xb** + **Xc**) × 100; product ratios and conversion determined via ^{1}H NMR. Naph = 2-Naphthyl.

Table 6. Acetylation of Methyl 4,6-*O*-Benzylidene-α-D-galactopyranoside 13 with NMI and Tetrapeptide Catalysts 1 and 2



Entry	Catalyst	13a [%]	13b [%]	13c [%]	*C* (%)	Selectivity (%)[c]
1	none	-	-	-	-	
2	NMI[a]	25	35	3	63	56
3	**2**[b]	26	69	6	>95	68
4	**1**[b]	22	65	3	90	72

[a]10 mol % cat., c = 0.01 mol L^{-1}. [b]5 mol % cat., c = 0.01 mol L^{-1}. [c]x = **13b**/(**13a** + **13b** + **13c**) × 100; product ratios and conversion determined via ^{1}H NMR.

desired methyl 2-*O*-acetyl-4,6-*O*-benzylidene-α-D-mannopyranoside **10a**.

We also investigated the influence of the 4,6-*O*-protecting group, first using again methylidene instead of benzylidene. NMI prefers formation of 3-*O*-acetylated product **11b** with an overall moderate conversion of 46% (Table 5, entry 1). Catalyst **1** showed similar reactivity to **10**; the formation of **11a** was favored with a selectivity of 68% (Table 5, entry 2). Applying the conditions from the DoE reduced the amount of diacetylated product **11c**, but the overall conversion (55%) dropped and the selectivity was just slightly increased to 73% (Table 5, entry 3). Using methyl 4,6-*O*-(2-naphthylidene)-α-D-mannopyranoside (**12**), which was already studied by us previously,[14] NMI gave only 22% conversion but was still favoring **12b** (Table 5, entry 4). Catalyst **1** provided a high selectivity of 70% for **12a**, and the overall conversion increased to 88% (Table 5, entry 5). The large amount of diacetylated product **12c** decreased employing the DoE conditions, thereby achieving a high selectivity of 86% (Table 5, entry 6). As found for **10**, the overall conversion dropped to 69%, but the ratio of mono-acetylated products **12a**:**b** remained at approximately 15:1—the highest we observed.

Isobutyric anhydride was also tested as the acylation reagent. NMI favored the formation of 3-*O*-acylated product **18b** with diacetylated product, and a moderate conversion of 54% was achieved (**18a**:**b**:**c** 6:42:6; Table S2, entry 2). Catalyst **1** provided a good selectivity of 75% for the 2-*O*-acylated product, but also a notable amount of the diacylated product formed. The overall conversion increased to 94% (**18a**:**b**:**c** 70:6:17; Table S2, entry 3).

For 4,6-*O*-benzylidene-α-D-galactopyranoside (**13**), NMI slightly favored **13b** with an overall moderate conversion of

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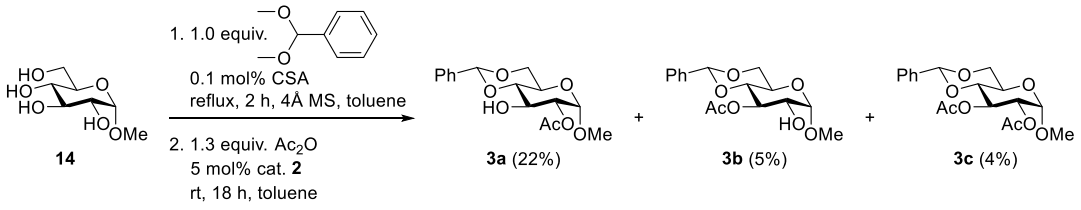
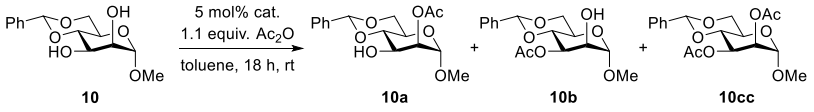
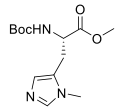
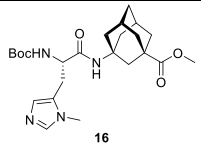
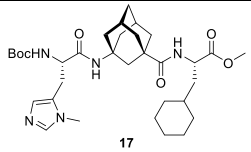
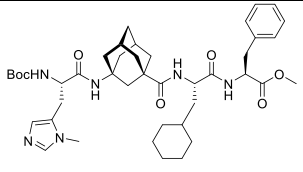


Figure 2. One-pot double protection of methyl α-D-glucopyranoside.

Table 7. Acetylation of Methyl 4,6-*O*-Benzylidene-α-D-mannopyranoside 10 with Catalysts with Increasing Size



Entry	Catalyst	10a [%]	10b [%]	10c [%]	*C* (%)	Selectivity (%)[a]
1	NMI	4	55	14	73	5
2	 15	8	39	14	61	13
3	 16	27	22	26	75	36
4	 17	63	8	20	91	69
5	 1	69	7	11	87	79

[a]x = **10a**/(**10a** + **10b** + **10c**) × 100; product ratios and conversion determined via ^{1}H NMR.

63% (Table 6, entry 2). Catalyst **2** did not change the preference for **13b** but slightly amplified the formation of it and increased the conversion to >95% (Table 6, entry 3). Catalyst **1** gave the best selectivity of 72% for **13b** and an overall conversion of 90% (Table 6, entry 4). These results again indicate that the change from an equatorial to an axial configuration at the C4-position has a significant influence on the interaction between the substrate and catalyst. Here too, this may in part be due to changes in the substrate hydrogen bonding patterns as the 3,4-*cis*-configuration in **13** would be expected to be more favorable for a hydrogen bond between the 3-OH and the 4-O.

Finally, we decided to determine whether it is possible to combine benzylidene protection followed by selective acetylation (Figure 2). Therefore, **14** was first benzylidene-protected using camphor sulfonic acid as the catalyst and toluene as the solvent, as well as 4 Å molecular sieves to remove the formed methanol. Subsequently, catalyst **2** and acetic anhydride were added. This procedure gave 22% 2-*O*-acetylated product **3a**, 5% 3-*O*-acetylated product **3b**, and 4% diacetylated product **3c**. The ratio (**3a**/**3b**/**3c** = ∼4:1:1) compares well with the results observed for methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (**3**) (Table 1, entry 4), and the overall yield is comparable to just the benzylidene protection of **14** (30% yield) under the given conditions; that is, the protection step limits the yield. This result indicates that the reactivity of the peptide is preserved even in a more complex system; **3** is selectively acetylated and the protection of all but one hydroxy group is achieved in a one-pot reaction sequence.

For almost all investigated pyranoside derivatives, the inherent reactivity, determined using NMI as the catalyst, was at the 3-OH group. Catalyst **2** and most other tested catalysts (Table S1) can switch the selectivity and preferably acylate the tested α-glucopyranosides at the 2-OH group under mild conditions with high yields. To do so, we expect the oligopeptides to form a "dynamic binding pocket," with which the monosaccharides can interact.[15,16] A first insight into the substrate recognition process is given by the fact that the selectivity essentially vanishes when using methyl 4,6-*O*-

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benzylidene-β-D-glucopyranoside (**6**) and methyl 4,6-*O*-benzylidene-α-D-galactopyranoside (**13**), which, like the glucopyranoside derivatives, also bears two *trans* OH-groups. This indicates that an axial α-position (the vicinal methoxy group has a *cis* relationship with the favored OH group) and an equatorial 4-*O*-position are necessary for a beneficial interaction between monosaccharide and oligopeptide **2**. The interaction seems to be different but even more important for methyl 4,6-*O*-benzylidene-α-D-mannopyranoside (**10**), which bears two *cis* OH-groups, as only oligopeptide catalyst **1** provides good selectivity. As shown in Table 7, selectivity increased with the size of the oligopeptide catalyst, which indicates that more interactions are beneficial for the reaction. NMI (5% selectivity; Table 7, entry **1**) and Boc-L-Pmh-OMe **15** (13% selectivity; Table 7, entry **2**), two catalysts which we expect to not interact with the substrates so much, favored the 3-*O*-position. By increasing the peptide chain length by one amino acid (Boc-L-Pmh-^{A}Gly-OMe **16**), the interaction is increased as well, evidenced by the increase in the 2-*O*-acetylated product formed (36% selectivity; Table 7, entry 3). Adding another amino acid (Boc-L-Pmh-^{A}Gly-L-Cha-OMe **17**) enables the formation of a binding pocket and results in enough interaction to selectively acylate in the 2-*O*-position (69% selectivity, Table 7, entry 4). Finally, catalyst **1** improved the selectivity further up to 79%. At this stage, we can only speculate about the exact nature of the interactions between the catalyst and substrate. We expect that hydrogen bonding interactions will play a key role as both substrates and catalysts have competent hydrogen-bonding donor and acceptor groups. To provide deeper insights into those interactions, we plan on executing detailed NMR studies in due course.[16]

CONCLUSIONS

We demonstrate that oligopeptides bearing Pmh as the catalytic moiety enable site-selective acylation reactions of pyranosides with anhydrides as the acylation reagents. For mannopyranoside and glucopyranoside derivatives, we show that tetrapeptides can selectively acylate the OH-group in the 2-position, leaving the monosaccharides with just one free OH group in the 3-position. The peptide catalyst structure overrides the intrinsic preference of the "parent" NMI motif for the 3-OH. A DoE approach was employed to optimize the reaction conditions for methyl 4,6-*O*-benzylidene-protected α-D-pyranosides; the optimal conditions vary for derivatives with other protecting groups. As our reaction conditions are mild and as we have demonstrated that it is possible to perform benzylidene protection followed by site-selective acylation in a one-pot reaction, our approach may also be amenable to other one-pot syntheses of orthogonally protected carbohydrate derivatives.

EXPERIMENTAL SECTION

General Information. All chemicals were purchased from commercial suppliers and used without further purification. Boc-4-aminoadamantanecarboxylic acid (Boc-^{A}Gly-OH),[22] Boc-Pmh-OH,[23] and H-Pmh-OMe·2HCl[24] were prepared according to literature procedures. Solvents for column chromatography, extractions, and filtrations were distilled prior to use. Dry solvents were purchased from Acros Organics (AcroSeal) and stored under a N_2 atmosphere and over activated molecular sieves (3 or 4 Å). Acetic anhydride was distilled and stored under N_2. Column chromatography was carried out using silica gel 60 M (Macherey-Nagel; 0.040−0.063 mm, 230−400 mesh ASTM). Thin-layer chromatography was performed using precoated plastic sheets Polygram SIL G/UV 254 (Macherey-Nagel; 0.2 mm silica gel layer with fluorescent indicator). For visualization, UV light (254 nm) or staining solutions [$KMnO_4$: 2.5 g $KMnO_4$, 8.3 g K_2CO_3, 250 mL H_2O; Hanessian's stain: 12 g $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$, 0.5 g $(NH_4)_4Ce(SO_4)_4\cdot 4H_2O$, 15 mL concn H_2SO_4, 235 mL H_2O] were utilized. NMR spectra were recorded on Bruker AV600, AV400 or AV400HD spectrometers. Chemical shifts (δ) are given in parts per million (ppm) relative to the respective solvent residual peaks ($CDCl_3$: δ 7.26 and 77.16 ppm; DMSO-d_6: δ 2.50 and 39.52 ppm; MeOH-d_4: δ 3.31 and 49.00 ppm; acetone-d_6: δ 2.05 and 29.84 ppm). ^{1}H NMR data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, sept = septet, m = multiplet, br = broad, app = apparent, or combinations thereof), coupling constants (Hz), and integration. For ^{13}C NMR, the chemical shifts are given. High-resolution mass spectrometry (HRMS) was performed with a Bruker MicrOTof (ESI). IR spectra were measured with a Bruker Alpha spectrometer.

General Procedures. *Procedure 1: Synthesis of Standards.* The pyranoside derivative (1.0 equiv) and 4-dimethylaminopyridine (DMAP) (0.05 equiv) were dissolved in dichloromethane (DCM) (10 mL/mmol), the carboxylic acid anhydride (1.3 equiv) was added, and the solution was stirred at rt for 24 h. The reaction was quenched with MeOH (1 mL/mmol) and stirred for further 30 min. The solvent was removed under reduced pressure, and the crude products were purified via column chromatography to obtain the three desired products.

Procedure 2: Amide Bond Formation (Peptide Coupling). The amino acids (1.0 equiv), 1-ethyl-3-(3-dimethylaminopropyl)-carbodiimide (EDC·HCl; 1.2 equiv), and 1-hydroxybenzotriazole (HOBt; 1.2 equiv) were suspended in CH_2Cl_2 (10 mL/mmol). Triethylamine (Et_3N; 1.2 equiv) was added, and the mixture was stirred at rt for 24 h. It was diluted with EtOAc (50 mL/mmol) and subsequently washed three times (10 mL/mmol) each with 0.5 m citric acid solution, saturated aqueous $NaHCO_3$ solution, and brine. The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure to afford the crude peptide as a solid (if necessary, a column chromatography was performed).

Procedure 3: Boc-Deprotection. The Boc-protected peptide (1.0 equiv) was treated with 2 mL/mmol 4 M HCl in 1,4-dioxane, and the resulting solution was stirred for 60 min. The reaction flask was flushed with nitrogen to remove residual HCl, and the solvent was removed under reduced pressure. After drying in vacuo, the resulting peptide hydrochloride was directly used for the next coupling step.

Procedure 4: Boc-π-methyl Histidine (Boc-Pmh) Coupling. The amino acids (1.0 equiv), EDC·HCl (2.2 equiv), and HOBt (2.2 equiv) were suspended in 10 mL/mmol CH_2Cl_2. Et_3N (2.2 equiv) was added, and the mixture was stirred at rt for 24 h. It was diluted with EtOAc (50 mL/mmol) and subsequently washed three times (10 mL/mmol) each with saturated aqueous $NaHCO_3$ solution and brine. The organic layer was dried over Na_2SO_4, filtered, and concentrated under reduced pressure. The product was obtained after column chromatography as a colorless solid.

General Procedure for the Catalyzed Reactions. The catalyzed reactions were carried out on a 0.1 mmol scale in dry toluene. The starting material and the catalyst were dissolved, and after 15 min stirring at the desired temperature, acetic anhydride was added. The resulting mixture was stirred for the desired time at the given temperature. Afterward, some drops of methanol were added to quench the reaction. All volatiles were removed under reduced pressure, and the residue was dissolved in a deuterated solvent and directly transferred to an NMR tube. The choice of the solvent was based on solubility and stability of all starting materials and the desired products. Selectivity and yields were determined by integration of signals in the ^{1}H NMR spectra, as shown in Figures S1−S12.

Procedure for Preparative Scale Reactions. The starting material and the catalyst were dissolved in dry toluene, and after 15 min stirring at the desired temperature, acetic anhydride was added. The resulting mixture was stirred for the desired time at the given temperature. Afterward, some drops of methanol were added to quench the reaction. All volatiles were removed under reduced

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pressure, and the crude product was purified via column chromatography to give the desired products.

Starting Materials. *Methyl 4,6-O-Methylidene-α-D-glucopyranoside (**4**).* The title compound was synthesized according to a literature procedure.[25] The crude product was purified via column chromatography (acetone/Et_2O 1:1), and it was obtained in 2.24 g yield (10.9 mmol, 22%) as a colorless solid. R_f = 0.23 (acetone/Et_2O 1:1). ^1H NMR (400 MHz, $CDCl_3$): δ 5.06 (d, J = 6.3 Hz, 1H), 4.74 (d, J = 3.9 Hz, 1H), 4.61 (d, J = 6.3 Hz, 1H), 4.14 (dd, J = 10.3, 4.9 Hz, 1H), 3.86 (td, J = 9.2, 2.1 Hz, 1H), 3.67 (ddd, J = 10.6, 9.5, 4.9 Hz, 1H), 3.57 (td, J = 9.3, 3.9 Hz, 1H), 3.43 (m, 4H), 3.28 (d, J = 2.4 Hz, 1H), 3.21 (t, J = 9.4 Hz, 1H), 2.69 (d, J = 9.4 Hz, 1H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 99.9, 93.9, 80.8, 73.1, 71.7, 68.8, 62.7, 55.7 ppm.

*Methyl 4,6-O-Cyclohexylidene-α-D-glucopyranoside (**5**).* The title compound was synthesized according to a literature procedure.[27] The crude product was purified via column chromatography (EtOAc), and it was obtained in 0.33 g (1.2 mmol, 12%) yield as a colorless solid. R_f = 0.28 (EtOAc). ^1H NMR (400 MHz, MeOH-d_4): δ 4.67 (d, J = 3.8 Hz, 1H), 3.83−3.71 (m, 2H), 3.64 (t, J = 9.0 Hz, 1H), 3.59−3.43 (m, 3H), 3.39 (s, 3H), 2.15−1.84 (m, 2H), 1.71−1.35 (m, 8H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, MeOH-d_4): δ 102.0, 100.9, 74.5, 74.1, 72.4, 64.9, 62.8, 55.7, 39.1, 28.8, 26.8, 23.8, 23.5 ppm.[26]

*Methyl 4,6-O-Benzylidene-β-D-glucopyranoside (**6**).* The title compound was synthesized according to a literature procedure.[27] The crude product was purified via column chromatography (EtOAc), and it was obtained in 5.22 g (18.5 mmol, 88%) yield as a colorless solid. R_f = 0.39 (EtOAc). ^1H NMR (400 MHz, DMSO-d_6): δ 7.49−7.41 (m, 2H), 7.41−7.34 (m, 3H), 5.57 (s, 1H), 5.31 (dd, J = 16.9, 5.0 Hz, 2H), 4.26 (d, J = 7.8 Hz, 1H), 4.20 (dd, J = 10.3, 4.1 Hz, 1H), 3.70 (td, J = 8.2, 6.9, 3.6 Hz, 1H), 3.50−3.29 (m, 4H), 3.08 (td, J = 8.0, 4.7 Hz, 1H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, DMSO-d_6): δ 137.8, 128.8, 128.0, 126.3, 104.5, 100.6, 80.6, 74.2, 72.8, 67.9, 65.8, 56.3 ppm.[28]

*1,2,3,4,6-Pentaacetate-D-glucopyranose (**7d**).*[29] 19.85 g (110 mmol, 1.0 equiv) of D-glucose and 10.75 g (131 mmol, 1.2 equiv) of sodium acetate were dissolved in 100 mL of acetic anhydride. After stirring for 8 h at 80 °C, the solution was poured onto 300 mL of ice and extracted with DCM (3 × 200 mL). The combined organic layers were washed with sat. aq. $NaHCO_3$ (2 × 150 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Recrystallization from ethanol gave 35.0 g (89.7 mmol, 82%) of **7d** (mixture α/β 1:4) as a colorless solid. ^1H NMR (400 MHz, $CDCl_3$): δ 6.27 (d, J = 3.7 Hz, 1H α), 5.65 (d, J = 8.3 Hz, 1H β), 5.41 (t, J = 9.9 Hz, 1H α), 5.19 (t, J = 9.4 Hz, 1H β), 5.11−5.01 (m, 2H α, 2H β), 4.27−4.18 (m, 1H α, 1H β), 4.09−4.00 (m, 2H α, 1H β), 3.77 (ddd, J = 10.0, 4.5, 2.2 Hz, 1H β), 2.14−1.92 (m, 15H α, 15H β) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 170.8, 170.7, 170.4, 170.2, 169.8, 169.5, 169.4, 169.1, 168.9, 91.8, 89.2, 72.9, 72.8, 70.3, 70.0, 69.3, 68.0, 67.9, 61.6, 21.0, 21.0, 20.8, 20.8, 20.7, 20.6 ppm.[30]

*(4-Methylphenyl)-1-thio-2,3,4,6-pentaacetate-β,D-glucopyranoside (**7e**).*[29] 31.2 g (80.0 mmol, 1.0 equiv) of **7d** and 10.8 g (88 mmol, 1.1 equiv) of *p*-toluene thiol were dissolved in 200 mL of dry DCM. The solution was cooled to 0 °C and 48.4 g (36 mL, 340 mmol, 4.25 equiv) of $BF_3{\cdot}Et_2O$ was slowly added. After stirring for 18 h at rt, the solution was poured onto 200 mL of ice and extracted with DCM (3 × 100 mL). The combined organic layers were washed with sat. aq. $NaHCO_3$ (2 × 150 mL), dried over Na_2SO_4, and concentrated under reduced pressure. Column chromatography (*n*-hexane/EtOAc 2:1) gave **7e** as a colorless solid (yield not determined as only a part of the crude product was purified). R_f = 0.24 (*n*-hexane/EtOAc 2:1). ^1H NMR (400 MHz, $CDCl_3$): δ 7.42−7.35 (m, 2H), 7.16−7.09 (m, 2H), 5.20 (t, J = 9.4 Hz, 1H), 5.02 (t, J = 9.8 Hz, 1H), 4.93 (dd, J = 10.1, 9.2 Hz, 1H), 4.63 (d, J = 10.0 Hz, 1H), 4.26−4.13 (m, 2H), 3.69 (ddd, J = 10.1, 4.8, 2.7 Hz, 1H), 2.35 (s, 3H), 2.09 (s, 3H), 2.08 (s, 3H), 2.01 (s, 3H), 1.98 (s, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 170.7, 170.3, 169.5, 169.4, 138.9, 134.0, 129.8, 127.7, 86.90, 75.9, 74.2, 70.1, 68.4, 62.3, 21.3, 20.9, 20.9, 20.7, 20.7 ppm.[31]

*(4-Methylphenyl)-1-thio-β,D-glucopyranoside (**7f**).*[29] 0.124 g (5.4 mmol, 1.2 equiv) of sodium was dissolved in 20 mL of dry methanol, and 2.05 g (4.5 mmol, 1 equiv) of **7e** were added. After stirring for 18 h, the solution was neutralized with Amberlyst 15(H), filtered off, and all volatiles were removed under reduced pressure to give 1.30 g of the desired product **7f** as a colorless solid, which was used in the next step without any further purification.

*(4-Methylphenyl)-4,6-O-benzylidene-1-thio-β,D-glucopyranoside (**7**).* 1.30 g (4.5 mmol, 1.0 equiv) of **7g**, 0.90 g (0.89 mL, 5.9 mmol, 1.3 equiv) of benzaldehyde dimethyl acetal, and 2 mg (0.01 mmol, 0.0025 equiv) of camphor sulfonic acid were suspended in 20 mL of chloroform. The suspension was placed into a preheated oil bath (90 °C), and chloroform was continuously distilled off. After distilling off, another 15 mL of chloroform were added. This procedure was repeated five times, and the mixture was then filtered while hot. After cooling to rt, all volatiles were removed under reduced pressure, and the residue was purified by column chromatography (*n*-hexane/EtOAc 1:1) to obtain **7** in 1.18 g (3.2 mmol, 70%) yield as a colorless solid. R_f = 0.37 (*n*-hexane/EtOAc 1:1). ^1H NMR (400 MHz, $CDCl_3$): δ 7.51−7.40 (m, 4H), 7.44−7.31 (m, 3H), 7.18−7.12 (m, 2H), 5.52 (s, 1H), 4.55 (d, J = 9.7 Hz, 1H), 4.41−4.33 (m, 1H), 3.88−3.69 (m, 2H), 3.54−3.43 (m, 2H), 3.42 (dd, J = 9.7, 8.5 Hz, 1H), 2.88 (s, 1H), 2.72 (s, 1H), 2.36 (s, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 139.0, 137.0, 133.8, 130.0, 129.5, 128.5, 127.4, 126.4, 102.1, 88.8, 80.4, 74.7, 72.6, 70.7, 68.7, 21.3 ppm.[32]

*Methyl 4,6-O-Benzylidene-α-D-mannopyranoside (**10**).* The title compound was synthesized according to a literature procedure.[33] The crude product was purified via column chromatography, and it was obtained in 0.97 g (3.4 mmol, 17%) yield as a colorless solid. R_f = 0.34 (*n*-hexane/EtOAc 1:2). ^1H NMR (400 MHz, MeOH-d_4): δ 7.55−7.46 (m, 2H), 7.38−7.29 (m, 3H), 5.60 (s, 1H), 4.67 (s, 1H), 4.20 (dd, J = 10.0, 4.7 Hz, 1H), 3.97−3.86 (m, 3H), 3.81 (t, J = 10.2 Hz, 1H), 3.74−3.67 (m, 1H), 3.39 (s, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, MeOH-d_4): δ 139.3, 129.9, 129.0, 127.5, 103.7, 103.4, 80.2, 72.6, 69.9, 69.6, 65.1, 55.3 ppm.

*Methyl 4,6-O-Methylidene-α-D-mannopyranoside (**11**).* The title compound was synthesized according to a literature procedure.[25] The crude product was purified via column chromatography (acetone/Et_2O 2:7), and it was obtained in 0.59 g (2.9 mmol, 29%) yield as a colorless solid. R_f = 0.47 (acetone/Et_2O 2:7). ^1H NMR (400 MHz, MeOH-d_4): δ 5.00 (d, J = 6.2 Hz, 1H), 4.66 (d, J = 6.2 Hz, 1H), 4.62 (d, J = 1.5 Hz, 1H), 4.05 (dd, J = 9.5, 3.7 Hz, 1H), 3.87−3.76 (m, 2H), 3.67−3.48 (m, 3H), 3.36 (s, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, MeOH-d_4): δ 103.7, 95.1, 80.1, 72.6, 69.6, 69.5, 65.3, 55.3 ppm.

*Methyl 4,6-O-(2-Naphthylidene)-α-D-mannopyranoside (**12**).* The title compound was synthesized according to a literature procedure.[14] The crude product was purified via column chromatography (*n*-hexane/EtOAc 1:2), and it was obtained in 0.85 g (2.6 mmol, 12%) yield as a colorless solid. R_f = 0.31 (*n*-hexane/EtOAc 1:2). ^1H NMR (400 MHz, MeOH-d_4): δ 8.01−7.98 (m, 1H), 7.91−7.80 (m, 3H), 7.62 (dd, J = 8.6, 1.7 Hz), 7.53−7.45 (m, 2H), 5.77 (s, 1H), 4.69 (d, J = 1.5 Hz, 1H), 4.25 (dd, J = 10.0, 4.8 Hz, 1H), 4.04−3.82 (m, 4H), 3.76 (ddd, J = 10.3, 8.8, 4.7 Hz, 1H), 3.41 (s, 3H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, MeOH-d_4): δ 136.7, 135.1, 134.3, 129.3, 128.7, 128.7, 127.4, 127.2, 126.8, 125.2, 103.8, 103.4, 80.3, 72.6, 70.0, 69.6, 65.1, 55.4 ppm.

*Methyl 4,6-O-Benzylidene-α-D-galactopyranoside (**13**).* The title compound was synthesized according to a literature procedure.[27] The product was obtained in 4.56 g (16.2 mmol, 90%) yield as a colorless solid. ^1H NMR (400 MHz, $CDCl_3$): δ 7.52−7.47 (m, 2H), 7.40−7.34 (m, 3H), 5.54 (s, 1H), 4.92 (d, J = 3.1 Hz, 1H), 4.28 (dd, J = 12.5, 1.6 Hz, 1H), 4.25−4.24 (m, 1H), 4.07 (dd, J = 12.6, 1.8 Hz, 1H), 3.96−3.86 (m, 2H), 3.68 (d, J = 1.6 Hz, 1H), 3.45 (s, 3H), 2.37 (s, 2H) ppm. $^{13}C\{^1H\}$ NMR (100 MHz, $CDCl_3$): δ 137.7, 129.3, 1284, 126.4, 101.4, 100.4, 76.0, 70.0, 69.9, 69.5, 62.9, 55.9 ppm.[34]

Standards. *Methyl 2-O-Acetyl-4,6-O-benzylidene-α,D-glucopyranoside (**3a**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **3a** after column chromatography (*n*-

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hexane/EtOAc 1:1) in 62.1 mg (0.19 mmol, 19%) yield as a colorless solid. R_f = 0.42 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.53−7.48 (m, 2H), 7.43−7.34 (m, 3H), 5.55 (s, 1H), 4.96 (d, J = 3.7 Hz, 1H), 4.81 (dd, J = 9.7, 3.8 Hz, 1H), 4.30 (dd, J = 9.9, 4.5 Hz, 1H), 4.18 (t, J = 9.5 Hz, 1H), 3.85 (td, J = 9.6, 4.5 Hz, 1H), 3.76 (t, J = 10.2 Hz, 1H), 3.56 (t, J = 9.3 Hz, 1H), 3.41 (s, 3H), 2.46 (bs, 1H), 2.16 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 170.8, 137.1, 129.5, 128.5, 126.4, 102.2, 97.7, 81.5, 73.7, 69.0, 68.8, 62.1, 55.6, 21.1 ppm.[35]

*Methyl 3-O-Acetyl-4,6-O-benzylidene-α,D-glucopyranoside (**3b**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **3b** after column chromatography (*n*-hexane/EtOAc 1:1) in 183.7 mg (0.51 mmol, 51%) yield as a colorless solid. R_f = 0.26 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.48−7.42 (m, 2H), 7.39−7.33 (m, 3H), 5.49 (s, 1H), 5.32 (t, J = 9.7 Hz, 1H), 4.81 (d, J = 3.8 Hz, 1H), 4.30 (dd, J = 10.2, 4.7 Hz, 1H), 3.87 (td, J = 9.8, 4.7 Hz, 1H), 3.75 (t, J = 10.3 Hz, 1H), 3.66 (dd, J = 9.5, 3.8 Hz, 1H), 3.58 (t, J = 9.6 Hz, 1H), 3.47 (s, 3H), 2.12 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 171.2, 137.1, 129.2, 128.4, 126.3, 101.7, 100.2, 78.8, 72.4, 72.0, 69.0, 62.9, 55.7, 21.2 ppm.[36]

*Methyl 2,3-O-Diacetyl-4,6-O-benzylidene-α,D-glucopyranoside (**3c**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **3b** after column chromatography (*n*-hexane/EtOAc 1:1) in 43.9 mg (0.12 mmol, 12%) yield as a colorless solid. R_f = 0.63 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.49−7.41 (m, 2H), 7.40−7.31 (m, 3H), 5.58 (t, J = 9.7 Hz, 1H), 5.51 (s, 1H), 4.96−4.88 (m, 2H), 4.30 (dd, J = 10.3, 4.8 Hz, 1H), 3.93 (td, J = 9.9, 4.8 Hz, 1H), 3.77 (t, J = 10.3 Hz, 1H), 3.65 (t, J = 9.6 Hz, 1H), 3.41 (s, 3H), 2.09 (s, 3H), 2.05 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 170.6, 169.9, 137.1, 129.2, 128.4, 126.3, 101.7, 97.8, 79.4, 71.7, 69.1, 69.0, 62.5, 55.5, 21.0, 20.9 ppm.[37]

*Methyl 2-O-Acetyl-4,6-O-methylidene-α,D-glucopyranoside (**4a**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-glucopyranoside (206.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **3a** after column chromatography (CH_2Cl_2/MeOH 40:1) in 46.9 mg (0.19 mmol, 19%) yield as a colorless solid. R_f = 0.17 (CH_2Cl_2/MeOH 40:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ 5.02 (d, J = 6.3 Hz, 1H), 4.85 (d, J = 3.8 Hz, 1H), 4.67 (dd, J = 9.7, 3.8 Hz, 1H), 4.58 (d, J = 6.3 Hz, 1H), 4.09 (dd, J = 10.3, 4.9 Hz, 1H), 4.05 (t, J = 9.5 Hz, 1H), 3.66 (td, J = 10.0, 4.9 Hz, 1H), 3.42 (t, J = 10.4 Hz, 1H), 3.32 (s, 3H), 3.23 (t, J = 9.4 Hz, 1H), 2.09 (s, 3H) ppm. ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$): δ 170.9, 97.6, 94.0, 81.2, 77.4, 77.2, 77.0, 73.9, 68.8, 68.8, 62.3, 55.5, 21.1 ppm. HRMS (ESI-TOF) m/z: [M + Na]$^+$ calcd for $C_{10}H_{16}O_7Na$, 271.0788; found, 271.0788. IR (ATR) ν/cm^{-1}: 3542, 3432, 2944, 2852, 1717, 1471, 1374, 1341, 1243, 1226, 1199, 1168, 1142, 1114, 1095, 1042, 1023, 987, 969, 921.

*Methyl 3-O-Acetyl-4,6-O-methylidene-α,D-glucopyranoside (**4b**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-glucopyranoside (206.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **4b** after column chromatography (CH_2Cl_2/MeOH 40:1) in 40.4 mg (0.16 mmol, 16%) yield as a colorless solid. R_f = 0.26 (CH_2Cl_2/MeOH 40:1). ^{1}H NMR (600 MHz, $CDCl_3$): δ 5.23 (t, J = 9.7 Hz, 1H), 5.03 (d, J = 6.3 Hz, 1H), 4.76 (d, J = 3.8 Hz, 1H), 4.56 (d, J = 6.3 Hz, 1H), 4.16 (dd, J = 10.4, 4.9 Hz, 1H), 3.74 (td, J = 9.9, 4.9 Hz, 1H), 3.61 (dd, J = 9.6, 3.9 Hz, 1H), 3.48−3.42 (m, 4H), 3.29 (t, J = 9.6 Hz, 1H), 2.13 (s, 3H) ppm. ^{13}C{^{1}H} NMR (150 MHz, $CDCl_3$): δ 171.3, 100.1, 93.8, 78.8, 72.4, 71.8, 68.8, 63.0, 55.7, 21.2. HRMS (ESI-TOF) m/z: [M + Na]$^+$ calcd for $C_{10}H_{16}O_7Na$, 271.0788; found, 271.0789. IR (ATR) ν/cm^{-1}: 3541, 3432, 2943, 2873, 1736, 1431, 1364, 1240, 1225, 1167, 1135, 1094, 1073, 1044, 1023, 985, 971, 920, 892.

*Methyl 2,3-O-Diacetyl-4,6-O-methylidene-α,D-glucopyranoside (**4c**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-glucopyranoside (206.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **4c** after column chromatography (CH_2Cl_2/MeOH 40:1) in 58.5 mg (0.20 mmol, 20%) yield as a colorless solid. R_f = 0.52 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.48 (t, J = 9.8 Hz, 1H), 5.04 (d, J = 6.2 Hz, 1H), 4.89 (d, J = 3.8 Hz, 1H), 4.85 (dd, J = 9.9, 3.8 Hz, 1H), 4.57 (d, J = 6.2 Hz, 1H), 3.81 (td, J = 9.9, 4.9 Hz, 1H), 3.47 (t, J = 10.3 Hz, 1H), 3.39 (s, 3H), 3.36 (t, J = 9.7 Hz, 1H), 2.07 (s, 3H), 2.06 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 170.5, 170.1, 97.7, 93.9, 79.5, 71.6, 69.1, 68.8, 62.6, 55.5, 20.9, 20.9 ppm.[38]

*Methyl 2-O-Acetyl-4,6-O-cyclohexylidene-α,D-glucopyranoside (**5a**). Procedure 1.* Methyl 4,6-*O*-cyclohexylidene-α,D-glucopyranoside (274.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **5a** after column chromatography (*n*-hexane/EtOAc 1:1) in 64.7 mg (0.20 mmol, 20%) yield as a colorless solid. R_f = 0.33 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 4.86−4.84 (m, 1H; overlap with OH of MeOH-d_4), 4.66 (dd, J = 9.7, 3.8 Hz, 1H), 3.87−3.75 (m, 3H), 3.65−3.54 (m, 2H), 3.35 (s, 3H), 2.09 (s, 3H), 2.07−1.97 (m, 1H), 1.97−1.87 (m, 1H), 1.71−1.36 (m, 8H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 172.2, 101.0, 99.0, 75.3, 74.5, 69.8, 64.8, 62.6, 55.6, 39.1, 28.8, 26.8, 23.8, 23.5, 20.7 ppm. HRMS (ESI-TOF) m/z: [M + Na]$^+$ calcd for $C_{15}H_{24}O_7Na$, 339.1414; found, 339.1416. IR (ATR) ν/cm^{-1}: 3446, 2935, 1741, 1446, 1367, 1235, 1194, 1146, 1124, 1097, 1027, 988, 950, 924.

*Methyl 3-O-Acetyl-4,6-O-cyclohexylidene-α,D-glucopyranoside (**5b**). Procedure 1.* Methyl 4,6-*O*-cyclohexylidene-α,D-glucopyranoside (274.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **5b** after column chromatography (*n*-hexane/EtOAc 1:1) in 40.4 mg (0.13 mmol, 13%) yield as a colorless solid. R_f = 0.39 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 5.13 (t, J = 9.5 Hz, 0H), 4.73 (d, J = 3.8 Hz, 1H), 3.86−3.75 (m, 2H), 3.70−3.60 (m, 3H), 3.43 (s, 3H), 2.09 (d, J = 12.2 Hz, 2H), 2.07 (s, 3H), 1.79−1.67 (m, 1H), 1.63−1.28 (m, 8H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 172.3, 102.0, 100.8, 73.8, 72.6, 72.1, 64.9, 62.8, 55.8, 39.0, 28.7, 26.7, 23.9, 23.7, 21.0 ppm. HRMS (ESI-TOF) m/z: [M + Na]$^+$ calcd for $C_{15}H_{24}O_7Na$, 339.1414; found, 339.1415. IR (ATR) ν/cm^{-1}: 3469, 2936, 1741, 1446, 1366, 1229, 1175, 1144, 1120, 1099, 1082, 1032, 990, 950, 925.

*Methyl 2,3-O-Diacetyl-4,6-O-cyclohexylidene-α,D-glucopyranoside (**5c**). Procedure 1.* Methyl 4,6-*O*-cyclohexylidene-α,D-glucopyranoside (274.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (132.7 mg, 122 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **5c** after column chromatography (*n*-hexane/EtOAc 1:1) in 58.5 mg (0.16 mmol, 16%) yield as a colorless solid. R_f = 0.66 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 5.30 (t, J = 9.6 Hz, 1H), 4.91 (d, J = 3.8 Hz, 1H), 4.88−4.84 (m, 2H), 3.86−3.81 (m, 2H), 3.78 (t, J = 9.6 Hz, 1H), 3.71−3.64 (m, 1H), 3.39 (s, 3H), 2.10 (d, J = 8.9 Hz, 1H), 2.03 (s, 3H), 2.03 (s, 3H), 1.84−1.72 (m, 1H), 1.65−1.28 (m, 7H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 171.7, 171.7, 101.1, 99.0, 72.8, 72.5, 71.0, 64.8, 62.6, 55.7, 38.9, 28.7, 26.6, 23.9, 23.7, 20.7, 20.5 ppm.[39]

*Methyl 2-O-Acetyl-4,6-O-benzylidene-β,D-glucopyranoside (**6a**). Procedure 1.* Methyl 4,6-*O*-benzylidene-β,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (112.6 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **6a** after column chromatography (*n*-hexane/EtOAc 1:1) in 89.0 mg (0.27 mmol, 27%) yield as a colorless solid. R_f = 0.42 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.49−7.34 (m, 5H), 5.61 (s, 1H), 5.54 (d, J = 5.5 Hz, 1H), 4.64 (dd, J = 9.2, 8.1 Hz, 1H), 4.52 (d, J = 8.1 Hz, 1H), 4.23 (dd, J = 10.2, 4.2 Hz, 1H), 3.80−3.63 (m, 2H), 3.56−3.45 (m, 2H), 3.37 (s, 3H), 2.04 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 169.1, 137.6, 128.9, 128.0, 126.3, 101.4, 100.7, 80.4, 74.1, 70.5, 67.7, 65.8, 56.2, 20.8 ppm.[35]

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*Methyl 3-O-Acetyl-4,6-O-benzylidene-β,D-glucopyranoside (**6b**). Procedure 1.* Methyl 4,6-*O*-benzylidene-β,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (112.6 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **6b** after column chromatography (*n*-hexane/EtOAc 1:1) in 121.0 mg (0.37 mmol, 37%) yield as a colorless solid. R_f = 0.29 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.37 (s, 5H), 5.62 (d, *J* = 5.5 Hz, 1H), 5.59 (s, 1H), 5.05 (t, *J* = 9.4 Hz, 1H), 4.42 (d, *J* = 7.6 Hz, 1H), 4.24 (dd, *J* = 10.1, 4.9 Hz, 1H), 3.74 (t, *J* = 10.1 Hz, 1H), 3.64 (t, *J* = 9.5 Hz, 1H), 3.54 (td, *J* = 9.7, 4.9 Hz, 1H), 3.43 (s, 3H), 3.33−3.26 (m, 2H), 2.03 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 169.6, 137.4, 128.8, 128.1, 126.0, 104.2, 100.2, 77.9, 73.6, 71.8, 67.8, 65.5, 56.5, 20.8 ppm.[36]

*Methyl 2,3-O-Diacetyl-4,6-O-benzylidene-β,D-glucopyranoside (**6c**). Procedure 1.* Methyl 4,6-*O*-benzylidene-β,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (112.6 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **6c** after column chromatography (*n*-hexane/EtOAc 1:1) in 66.1 mg (0.18 mmol, 18%) yield as a colorless solid. R_f = 0.62 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.37 (s, 5H), 5.63 (s, 1H), 5.29 (t, *J* = 9.4 Hz, 1H), 4.81 (dd, *J* = 9.2, 7.9 Hz, 1H), 4.74 (d, *J* = 7.9 Hz, 1H), 4.27 (dd, *J* = 9.9, 4.7 Hz, 1H), 3.82 (t, *J* = 9.6 Hz, 1H), 3.79 (t, *J* = 9.6 Hz, 1H), 3.70 (td, *J* = 9.7, 4.7 Hz, 1H), 3.39 (s, 3H), 2.01 (s, 3H), 1.99 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, DMSO-d_6): δ 169.5, 169.1, 137.2, 128.9, 128.1, 126.1, 101.0, 100.3, 77.5, 71.7, 71.4, 67.5, 65.4, 56.5, 20.4, 20.4 ppm.[37]

*4-Methylphenyl 2-O-Acetyl-4,6-O-benzylidene-1-thio-β,D-glucopyranoside (**7a**). Procedure 1.* 4-Methylphenyl 4,6-*O*-benzylidene-1-thio-β,D-glucopyranoside (480.0 mg, 1.3 mmol, 1.0 equiv), DMAP (15.7 mg, 0.13 mmol, 0.1 equiv), Ac_2O (169.9 mg, 170 μL, 1.7 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain a mixture of **7a** and **7b** after column chromatography (*n*-hexane/EtOAc 2:1) as a colorless solid. Analytical amounts of the mixture were subsequently separated by HPLC. R_f = 0.36 (*n*-hexane/EtOAc 2:1). Retention time = 9.25 min (Eurospher II CN column, eluent: 15% EtOAc/*n*-hexane, 0.477 CV/min, UV-detector λ = 254 nm). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.51−7.43 (m, 2H), 7.42−7.33 (m, 5H), 7.14 (d, *J* = 7.8 Hz, 2H), 5.53 (s, 1H), 4.91 (dd, *J* = 10.0, 8.8 Hz, 1H), 4.68 (d, *J* = 10.0 Hz, 1H), 4.38 (dd, *J* = 10.5, 4.7 Hz, 1H), 3.91 (td, *J* = 8.8, 2.3 Hz, 1H), 3.78 (dd, *J* = 10.5, 9.5 Hz, 1H), 3.58−3.45 (m, 2H), 2.50 (d, *J* = 3.2 Hz, 1H), 2.35 (s, 3H), 2.19 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 170.2, 138.8, 137.0, 133.7, 129.5, 128.5, 128.2, 126.4, 102.1, 86.9, 80.8, 73.8, 72.6, 70.4, 68.7, 21.3, 21.2 ppm.[40]

*4-Methylphenyl 3-O-Acetyl-4,6-O-benzylidene-1-thio-β,D-glucopyranoside (**7b**). Procedure 1.* 4-Methylphenyl 4,6-*O*-benzylidene-1-thio-β,D-glucopyranoside (480.0 mg, 1.3 mmol, 1.0 equiv), DMAP (15.7 mg, 0.13 mmol, 0.1 equiv), Ac_2O (169.9 mg, 170 μL, 1.7 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain a mixture of **7a** and **7b** after column chromatography (*n*-hexane/EtOAc 2:1) as a colorless solid. Analytical amounts of the mixture were subsequently separated by HPLC. R_f = 0.37 (*n*-hexane/EtOAc 2:1). Retention time = 8.14 min (Eurospher II CN column, eluent: 15% EtOAc/*n*-hexane, 0.477 CV/min, UV-detector λ = 254 nm). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.49−7.39 (m, 4H), 7.39−7.31 (m, 3H), 7.16 (d, *J* = 7.6 Hz, 2H), 5.48 (s, 1H), 5.23 (t, *J* = 9.0 Hz, 1H), 4.62 (d, *J* = 9.6 Hz, 1H), 4.38 (dd, *J* = 10.5, 4.5 Hz, 1H), 3.77 (dd, *J* = 10.6, 9.4 Hz, 1H), 3.62−3.46 (m, 3H), 2.73 (s, 1H), 2.37 (s, 3H), 2.11 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 171.1, 139.1, 137.0, 134.0, 130.1, 129.3, 128.4, 127.2, 126.3, 101.6, 89.5, 78.4, 74.9, 74.9, 71.6, 71.0, 68.7, 21.3, 21.1. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{22}H_{24}O_6SNa$, 439.1186; found, 439.1188. IR (ATR) ν/cm^{-1}: 3387, 2866, 1743, 1716, 1494, 1453, 1366, 1311, 1237, 1076, 1028, 964, 808, 741, 695.

*4-Methylphenyl 2,3-O-Diacetyl-4,6-O-benzylidene-1-thio-β,D-glucopyranoside (**7c**). Procedure 1.* 4-Methylphenyl 4,6-*O*-benzylidene-1-thio-β,D-glucopyranoside (480.0 mg, 1.3 mmol, 1.0 equiv), DMAP (15.7 mg, 0.13 mmol, 0.1 equiv), Ac_2O (169.9 mg, 170 μL, 1.7 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **7c** after column chromatography (*n*-hexane/EtOAc 2:1) in 154.0 mg (0.34 mmol, 26%) yield as a colorless solid. R_f = 0.56 (*n*-hexane/EtOAc 2:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.47−7.32 (m, 7H), 7.15 (d, *J* = 7.9 Hz, 2H), 5.49 (s, 1H), 5.33 (t, *J* = 9.3 Hz, 1H), 4.97 (dd, *J* = 10.0, 8.9 Hz, 1H), 4.74 (d, *J* = 10.0 Hz, 1H), 4.38 (dd, *J* = 10.5, 4.9 Hz, 1H), 3.78 (t, *J* = 10.2 Hz, 1H), 3.64 (t, *J* = 9.5 Hz, 1H), 3.55 (td, *J* = 9.6, 4.9 Hz, 1H), 2.36 (s, 3H), 2.11 (s, 3H), 2.03 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 170.1, 169.5, 138.8, 136.8, 133.7, 129.8, 129.2, 128.3, 127.7, 126.2, 101.5, 86.8, 78.1, 73.0, 70.8, 70.7, 68.5, 21.2, 20.9, 20.8 ppm.[41]

*Methyl 4,6-O-Benzylidene-2-O-isobutyryl-α,D-glucopyranoside (**8a**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (205.6 mg, 215 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **8a** after column chromatography (*n*-hexane/EtOAc 3:1) in 101.4 mg (0.29 mmol, 29%) yield as a colorless solid. R_f = 0.14 (*n*-hexane/EtOAc 3:1). ^{1}H NMR (400 MHz, acetone-d_6): δ 7.53−7.46 (m, 2H), 7.37 (m, 3H), 5.63 (s, 1H), 4.88 (d, *J* = 3.8 Hz, 1H), 4.70 (dd, *J* = 9.6, 3.8 Hz, 1H), 4.27−4.19 (m, 1H), 4.09−4.01 (m, 1H), 3.83−3.72 (m, 2H), 3.65−3.54 (m, 1H), 3.39 (s, 3H), 2.59 (sept, *J* = 7.0 Hz, 1H), 1.15 (dd, *J* = 7.0, 3.8 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, acetone-d_6): δ 176.9, 139.1, 129.6, 128.8, 127.3, 102.4, 98.7, 82.6, 74.6, 69.4, 69.1, 69.0, 63.4, 55.6, 34.5, 29.8, 19.3, 19.1 ppm.[8f]

*Methyl 4,6-O-Benzylidene-3-O-isobutyryl-α,D-glucopyranoside (**8b**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (205.6 mg, 215 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **8b** after column chromatography (*n*-hexane/EtOAc 3:1) in 100.4 mg (0.28 mmol, 28%) yield as a colorless solid. R_f = 0.19 (*n*-hexane/EtOAc 3:1). ^{1}H NMR (400 MHz, acetone-d_6): δ 7.46−7.40 (m, 2H), 7.38−7.31 (m, 3H), 5.60 (s, 1H), 5.30 (t, *J* = 9.6 Hz, 1H), 4.80 (d, *J* = 3.7 Hz, 1H), 4.31−4.21 (m, 1H), 3.89−3.75 (m, 2H), 3.73−3.62 (m, 2H), 3.45 (s, 3H), 2.82 (bs, 1H), 2.56 (sept, *J* = 7.0 Hz, 1H), 1.12 (dd, *J* = 7.0, 2.6 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, acetone-d_6): δ 176.7, 138.9, 129.5, 128.8, 127.0, 101.9, 101.7, 80.2, 72.7, 72.1, 69.5, 63.7, 55.8, 34.7, 19.5, 19.2 ppm.[8f]

*Methyl 4,6-O-Benzylidene-2,3-O-diisobutyryl-α,D-glucopyranoside (**8c**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-glucopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (205.6 mg, 215 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **8c** after column chromatography (*n*-hexane/EtOAc 3:1) in 98.1 mg (0.23 mmol, 23%) yield as a colorless solid. R_f = 0.50 (*n*-hexane/EtOAc 3:1). ^{1}H NMR (400 MHz, acetone-d_6): δ 7.47−7.41 (m, 2H), 7.39−7.30 (m, 3H), 5.66 (s, 1H), 5.57−5.50 (m, 1H), 4.96 (d, *J* = 3.7 Hz, 1H), 4.90 (dd, *J* = 9.9, 3.7 Hz, 1H), 4.34−4.23 (m, 1H), 3.91−3.80 (m, 3H), 3.44 (s, 3H), 2.54 (sept, *J* = 7.0 Hz, 1H), 2.53 (sept, *J* = 7.0 Hz, 1H), 1.13−1.08 (m, 12H) ppm. ^{13}C{^{1}H} NMR (100 MHz, acetone-d_6): δ 176.4, 176.2, 138.7, 129.6, 128.8, 127.0, 102.0, 98.7, 80.0, 72.04, 69.5, 69.3, 63.6, 55.8, 34.6, 34.5, 19.4, 19.2, 19.2, 19.1 ppm. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{22}H_{30}O_8Na$, 455.1835; found, 455.1833. IR (ATR) ν/cm^{-1}: 2973, 2931, 1745, 1738, 1454, 1370, 1342, 1257, 1184, 1147, 1121, 1093, 1049, 1026, 1004, 989, 923, 750, 699.

*Methyl 4,6-O-Methylidene-2-O-isobutyryl-α,D-glucopyranoside (**9a**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-glucopyranoside (206.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (205.6 mg, 215 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **9a** after column chromatography (*n*-hexane/EtOAc 2:1) in 65.4 mg (0.24 mmol, 24%) yield as a colorless solid. R_f = 0.22 (*n*-hexane/EtOAc 2:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ δ 5.22 (t, *J* = 9.7 Hz, 1H), 5.03 (d, *J* = 6.2 Hz, 1H), 4.75 (d, *J* = 3.8 Hz, 1H), 4.56 (d, *J* = 6.3 Hz, 1H), 4.16 (dd, *J* = 10.1, 5.0 Hz, 1H), 3.74 (td, *J* = 10.0, 4.9 Hz, 1H), 3.61 (dd, *J* = 9.6, 3.9 Hz, 1H), 3.45 (t, *J* = 10.3 Hz, 1H), 3.45 (s, 3H), 3.30 (t, *J* = 9.6 Hz, 1H), 2.62 (sept, *J* = 7.0 Hz, 1H), 2.09 (s, 1H), 1.19 (dd, *J* = 7.0, 5.0 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 177.4, 100.2, 100.1, 93.8, 79.0, 72.1, 71.9, 68.8, 63.0, 55.7, 34.2, 19.1, 19.1 ppm.[8f]

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*Methyl 4,6-O-Methylidene-3-O-isobutyryl-α,D-glucopyranoside (**9b**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-glucopyranoside (206.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (205.6 mg, 215 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **9b** after column chromatography (*n*-hexane/EtOAc 2:1) in 69.2 mg (0.25 mmol, 25%) yield as a colorless solid. R_f = 0.23 (*n*-hexane/EtOAc 2:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ δ 5.22 (t, *J* = 9.7 Hz, 1H), 5.03 (d, *J* = 6.2 Hz, 1H), 4.75 (d, *J* = 3.8 Hz, 1H), 4.56 (d, *J* = 6.3 Hz, 1H), 4.16 (dd, *J* = 10.1, 5.0 Hz, 1H), 3.74 (td, *J* = 10.0, 4.9 Hz, 1H), 3.61 (dd, *J* = 9.6, 3.9 Hz, 1H), 3.45 (t, *J* = 10.3 Hz, 1H), 3.45 (s, 3H), 3.30 (t, *J* = 9.6 Hz, 1H), 2.62 (sept, *J* = 7.0 Hz, 1H), 2.09 (s, 1H), 1.19 (dd, *J* = 7.0, 5.0 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 177.4, 100.2, 100.1, 93.8, 79.0, 72.1, 71.9, 68.8, 63.0, 55.7, 34.2, 19.1, 19.1 ppm.[8f]

*Methyl 4,6-O-Methylidene-2,3-O-diisobutyryl-α,D-glucopyranoside (**9c**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-glucopyranoside (206.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (205.6 mg, 215 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **9c** after column chromatography (*n*-hexane/EtOAc 2:1) in 89.1 mg (0.26 mmol, 26%) yield as a colorless solid. R_f = 0.57 (*n*-hexane/EtOAc 2:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.52 (t, *J* = 9.7 Hz, 1H), 5.04 (d, *J* = 6.2 Hz, 1H), 4.89 (d, *J* = 3.8 Hz, 1H), 4.85 (dd, *J* = 9.7, 3.8 Hz, 1H), 4.57 (d, *J* = 6.2 Hz, 1H), 4.17 (dd, *J* = 10.3, 4.9 Hz, 1H), 3.82 (td, *J* = 9.9, 4.9 Hz, 1H), 3.48 (t, *J* = 10.3 Hz, 1H), 3.38 (s, 3H), 3.36 (t, *J* = 9.7 Hz, 1H), 2.54 (dp, *J* = 8.1, 7.0 Hz, 2H), 1.13 (t, *J* = 6.9 Hz, 12H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 176.6, 176.1, 97.7, 93.9, 79.6, 71.3, 68.8, 68.7, 62.6, 55.6, 34.1, 33.9, 19.1, 19.0, 18.9 ppm. HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{16}H_{26}O_8Na$, 369.1520; found, 369.1523 IR (ATR) ν/cm^{-1}: 2976, 2878, 1735, 1471, 1389, 1352, 1232, 1191, 1149, 1122, 1107, 1073, 1047, 1021, 991, 971, 921, 849.

*Methyl 2-O-Acetyl-4,6-O-benzylidene-α,D-mannopyranoside (**10a**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (113.4 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **10a** after column chromatography (*n*-hexane/EtOAc 2:1) in 48.0 mg (0.15 mmol, 15%) yield as a colorless solid. R_f = 0.45 (*n*-hexane/EtOAc 2:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.53−7.46 (m, 2H), 7.38−7.31 (m, 3H), 5.64 (s, 1H), 5.10 (dd, *J* = 3.7, 1.5 Hz, 1H), 4.67 (d, *J* = 1.6 Hz, 1H), 4.22 (dd, *J* = 9.7, 4.4 Hz, 1H), 4.12−4.06 (m, 1H), 3.91 (dd, *J* = 10.0, 9.0 Hz, 1H), 3.86−3.80 (m, 1H), 3.79−3.72 (m, 1H), 3.40 (s, 3H), 2.13 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 172.0, 139.2, 129.9, 129.3, 129.0, 127.8, 127.5, 103.3, 100.9, 80.2, 74.0, 69.7, 67.9, 65.0, 55.5, 20.8 ppm.[42]

*Methyl 3-O-Acetyl-4,6-O-benzylidene-α,D-mannopyranoside (**10b**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (113.4 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **10b** after column chromatography (*n*-hexane/EtOAc 2:1) in 224.5 mg (0.69 mmol, 69%) yield as a colorless solid. R_f = 0.29 (*n*-hexane/EtOAc 2:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.47−7.39 (m, 2H), 7.39−7.30 (m, 3H), 5.59 (s, 1H), 5.13 (dd, *J* = 10.3, 3.4 Hz, 1H), 4.69 (d, *J* = 1.6 Hz, 1H), 4.28−4.17 (m, 1H), 4.17−4.08 (m, 1H), 4.06 (dd, *J* = 3.7, 1.9 Hz, 1H), 3.90−3.77 (m, 2H), 3.41 (s, 3H), 2.07 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 172.3, 139.0, 130.0, 129.1, 127.5, 103.6, 103.3, 77.3, 72.4, 70.1, 69.8, 65.3, 55.4, 20.9, 20.9 ppm.[43]

*Methyl 2,3-O-Diacetyl-4,6-O-benzylidene-α,D-mannopyranoside (**10c**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (113.4 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **10c** after column chromatography (*n*-hexane/EtOAc 2:1) in 43.9 mg (0.12 mmol, 12%) yield as a colorless solid. R_f = 0.59 (*n*-hexane/EtOAc 2:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.48−7.40 (m, 2H), 7.37−7.30 (m, 3H), 5.63 (s, 1H), 5.31−5.25 (m, 2H), 4.72 (d, *J* = 1.3 Hz, 1H), 4.31−4.20 (m, 1H), 4.15−4.08 (m, 1H), 3.94−3.82 (m, 2H), 3.43 (s, 3H), 2.14 (s, 3H), 1.97 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 171.8, 171.6, 138.9, 130.1, 129.1, 127.5, 103.3, 101.0, 77.3, 71.1, 70.0, 69.7, 65.2, 55.6, 20.9, 20.6, 20.6 ppm.[44]

*Methyl 2-O-Acetyl-4,6-O-methylidene-α,D-mannopyranoside (**11a**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-mannopyranoside (128.0 mg, 0.62 mmol, 1.0 equiv), DMAP (8.0 mg, 0.06 mmol, 0.1 equiv), Ac_2O (82.0 mg, 76 μL, 0.81 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **11a** after column chromatography (*n*-hexane/EtOAc 1:1) in 30.0 mg (0.12 mmol, 12%) yield as a colorless solid. R_f = 0.24 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 5.07−5.03 (m, 1H), 4.97 (d, *J* = 6.3 Hz, 1H), 4.65 (d, *J* = 6.3 Hz, 1H), 4.63 (dd, *J* = 5.8, 1.6 Hz, 1H), 4.09−4.06 (m, 1H), 4.01 (dd, *J* = 3.4, 1.7 Hz, 1H), 3.87−3.81 (m, 1H), 3.74−3.67 (m, 1H), 3.60−3.52 (m, 2H), 3.39 (s, 3H), 2.08 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 172.2, 103.5, 95.0, 77.3, 72.3, 70.2, 69.5, 65.4, 55.4, 20.9 ppm.[14]

*Methyl 3-O-Acetyl-4,6-O-methylidene-α,D-mannopyranoside (**11b**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-mannopyranoside (128.0 mg, 0.62 mmol, 1.0 equiv), DMAP (8.0 mg, 0.06 mmol, 0.1 equiv), Ac_2O (82.0 mg, 76 μL, 0.81 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **11b** after column chromatography (*n*-hexane/EtOAc 1:1) in 3.1 mg (0.01 mmol, 2%) yield as a colorless solid. R_f = 0.08 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 5.13 (d, *J* = 0.8 Hz, 1H), 4.97−4.95 (m, 1H), 4.93−4.92 (m, 1H), 4.39 (dd, *J* = 11.9, 2.3 Hz, 1H), 4.17 (dd, *J* = 11.8, 6.4 Hz, 1H), 4.11−4.07 (m, 1H), 3.86 (dd, *J* = 5.6, 0.8 Hz, 1H), 3.70 (dddd, *J* = 10.4, 6.4, 2.3, 0.6 Hz, 1H), 3.44 (dd, *J* = 10.4, 7.4 Hz, 1H), 3.39 (s, 3H), 2.06 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 172.7, 99.4, 95.6, 79.3, 77.6, 69.1, 67.9, 64.8, 55.2, 20.7 ppm.[14]

*Methyl 2,3-O-Diacetyl-4,6-O-methtylidene-α,D-mannopyranoside (**11c**). Procedure 1.* Methyl 4,6-*O*-methylidene-α,D-mannopyranoside (128.0 mg, 0.62 mmol, 1.0 equiv), DMAP (8.0 mg, 0.06 mmol, 0.1 equiv), Ac_2O (82.0 mg, 76 μL, 0.81 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **11c** after column chromatography (*n*-hexane/EtOAc 1:1) in 82.0 mg (0.10 mmol, 17%) yield as a colorless solid. R_f = 0.51 (*n*-hexane/EtOAc 1:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 5.24 (dd, *J* = 3.6, 1.6 Hz, 1H), 5.22−5.17 (m, 1H), 5.00−4.95 (m, 1H), 4.69 (d, *J* = 6.3 Hz, 1H), 4.67 (d, *J* = 1.6 Hz, 1H), 4.14−4.07 (m, 1H), 3.84−3.74 (m, 2H), 3.57 (t, *J* = 10.1 Hz, 1H), 3.41 (s, 3H), 2.12 (s, 3H), 1.98 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 171.7, 171.5, 100.9, 95.0, 77.3, 71.1, 69.9, 69.3, 65.3, 55.6, 20.6, 20.6 ppm.[14]

*Methyl 2-O-Acetyl-4,6-O-(2-naphthylidene)-α,D-mannopyranoside (**12a**). Procedure 1.* Methyl 4,6-*O*-naphthylidene-α,D-mannopyranoside (169.0 mg, 0.51 mmol, 1.0 equiv), DMAP (6.1 mg, 0.05 mmol, 0.1 equiv), Ac_2O (66.4 mg, 61 μL, 0.66 mmol, 1.3 equiv), and 5 mL of DCM were used to obtain **12a** after column chromatography (*n*-hexane/EtOAc 1:2) in 110.0 mg (0.29 mmol, 58%) yield as a colorless solid. R_f = 0.50 (*n*-hexane/EtOAc 1:2). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.99 (s, 1H), 7.89−7.82 (m, 3H), 7.62 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.52−7.46 (m, 2H), 5.80 (s, 1H), 5.13 (dd, *J* = 3.7, 1.6 Hz, 1H), 4.69 (d, *J* = 1.5 Hz, 1H), 4.28 (dd, *J* = 9.8, 4.5 Hz, 1H), 4.13 (dd, *J* = 10.0, 3.7 Hz, 1H), 3.98 (dd, *J* = 10.1, 9.0 Hz, 1H), 3.92−3.85 (m, 1H), 3.84−3.77 (m, 1H), 3.41 (s, 3H), 2.15 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 172.0, 136.5, 135.1, 134.3, 129.3, 128.8, 128.7, 127.5, 127.2, 126.8, 125.2, 103.4, 100.9, 80.3, 74.0, 69.8, 68.0, 65.1, 55.5, 20.8 ppm.[14]

*Methyl 3-O-Acetyl-4,6-O-(2-naphthylidene)-α,D-mannopyranoside (**12b**). Procedure 1.* Methyl 4,6-*O*-naphthylidene-α,D-mannopyranoside (169.0 mg, 0.51 mmol, 1.0 equiv), DMAP (6.1 mg, 0.05 mmol, 0.1 equiv), Ac_2O (66.4 mg, 61 μL, 0.66 mmol, 1.3 equiv), and 5 mL of DCM were used to obtain **12b** after column chromatography (*n*-hexane/EtOAc 1:2) in 33.1 mg (0.09 mmol, 17%) yield as a colorless solid. R_f = 0.69 (*n*-hexane/EtOAc 1:2). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.92−7.88 (m, 1H), 7.86−7.79 (m, 3H), 7.54 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.48−7.43 (m, 2H), 5.72 (s, 1H), 5.19 (dd, *J* = 10.3, 3.3 Hz, 1H), 4.71 (d, *J* = 1.7 Hz, 1H), 4.33−4.18 (m, 2H), 4.10 (dd, *J* = 3.4, 1.6 Hz, 1H), 3.95−3.85 (m, 2H), 3.39 (s, 3H), 2.06 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 172.2, 136.3, 135.0,

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134.2, 129.3, 128.9, 128.7, 127.5, 127.2, 126.8, 125.0, 103.5, 103.4, 77.4, 72.4, 70.1, 69.8, 65.3, 55.4, 20.9 ppm.[14]

*Methyl 2,3-O-Diacetyl-4,6-O-(2-naphthylidene)-α,D-mannopyranoside (**12c**). Procedure 1.* Methyl 4,6-*O*-naphthylidene-α,D-mannopyranoside (169.0 mg, 0.51 mmol, 1.0 equiv), DMAP (6.1 mg, 0.05 mmol, 0.1 equiv), Ac_2O (66.4 mg, 61 μL, 0.66 mmol, 1.3 equiv), and 5 mL of DCM were used to obtain **12c** after column chromatography (*n*-hexane/EtOAc 1:2) in 44.0 mg (0.11 mmol, 21%) yield as a colorless solid. R_f = 0.79 (*n*-hexane/EtOAc 1:2). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.92 (s, 1H), 7.89−7.82 (m, 3H), 7.56 (dd, *J* = 8.5, 1.7 Hz, 1H), 7.51−7.46 (m, 2H), 5.80 (s, 1H), 5.34−5.28 (m, 2H), 4.74 (d, *J* = 1.3 Hz, 1H), 4.34−4.27 (m, 1H), 4.20−4.13 (m, 1H), 3.98−3.90 (m, 2H), 3.45 (s, 3H), 2.15 (s, 3H), 1.97 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 171.9, 171.6, 136.2, 135.2, 134.3, 129.3, 128.9, 128.7, 127.5, 127.3, 126.9, 125.0, 103.4, 101.0, 77.4, 71.1, 70.1, 69.7, 65.2, 55.6, 20.7, 20.6 ppm.[14]

*Methyl 2-O-Acetyl-4,6-O-benzylidene-α,D-galactopyranoside (**13a**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (113.4 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **13a** after column chromatography (*n*-hexane/EtOAc 1:2) in 115.3 mg (0.36 mmol, 36%) yield as a colorless solid. R_f = 0.29 (*n*-hexane/EtOAc 1:2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56−7.46 (m, 2H), 7.43−7.32 (m, 3H), 5.56 (s, 1H), 5.15 (dd, *J* = 10.3, 3.5 Hz, 1H), 4.98 (d, *J* = 3.5 Hz, 1H), 4.30 (dd, *J* = 4.9, 1.4 Hz, 1H), 4.28 (dd, *J* = 3.8, 1.4 Hz, 1H), 4.14−4.04 (m, 2H), 3.73 (q, *J* = 1.6 Hz, 1H), 3.42 (s, 3H), 2.14 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 171.2, 137.5, 129.4, 128.4, 126.5, 101.5, 98.3, 76.2, 71.4, 69.3, 67.4, 62.5, 55.7, 21.2 ppm.[18e]

*Methyl 3-O-Acetyl-4,6-O-benzylidene-α,D-galactopyranoside (**13b**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (113.4 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **13b** after column chromatography (*n*-hexane/EtOAc 1:2) in 151.7 mg (0.48 mmol, 48%) yield as a colorless solid. R_f = 0.38 (*n*-hexane/EtOAc 1:2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.55−7.45 (m, 2H), 7.41−7.30 (m, 3H), 5.51 (s, 1H), 5.12 (dd, *J* = 10.4, 3.4 Hz, 1H), 4.95 (d, *J* = 3.7 Hz, 1H), 4.37 (dd, *J* = 3.6, 1.2 Hz, 1H), 4.27 (dd, *J* = 12.5, 1.6 Hz, 1H), 4.17 (dd, *J* = 10.4, 3.8 Hz, 1H), 4.06 (dd, *J* = 12.5, 1.8 Hz, 1H), 3.72 (q, *J* = 1.7 Hz, 1H), 3.47 (s, 3H), 2.14 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 171.5, 137.8, 129.1, 128.3, 126.3, 100.9, 100.4, 77.5, 77.2, 76.8, 74.4, 71.8, 69.3, 66.9, 62.7, 55.8, 21.2 ppm.[18e]

*Methyl 2,3-O-Diacetyl-4,6-O-benzylidene-α,D-galactopyranoside (**13c**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), Ac_2O (113.4 mg, 105 μL, 1.1 mmol, 1.1 equiv), and 10 mL of DCM were used to obtain **13c** after column chromatography (*n*-hexane/EtOAc 1:2) in 50.4 mg (0.15 mmol, 15%) yield as a colorless solid. R_f = 0.65 (*n*-hexane/EtOAc 1:2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54−7.47 (m, 2H), 7.41−7.32 (m, 3H), 5.51 (s, 1H), 5.39−5.29 (m, 2H), 5.08 (d, *J* = 3.0 Hz, 1H), 4.46 (dd, *J* = 3.2, 1.2 Hz, 1H), 4.28 (dd, *J* = 12.5, 1.6 Hz, 1H), 4.06 (dd, *J* = 12.6, 1.8 Hz, 1H), 3.75 (q, *J* = 1.6 Hz, 1H), 3.42 (s, 3H), 2.08 (s, 3H), 2.08 (s, 3H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 170.8, 170.4, 137.7, 129.2, 128.3, 126.4, 101.0, 97.9, 74.1, 69.2, 68.7, 68.3, 62.2, 55.7, 21.1, 21.0 ppm.[45]

*Methyl 2-O-Isobutyryl-4,6-O-benzylidene-α,D-mannopyranoside (**18a**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (206 mg, 217 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **18a** after column chromatography (*n*-hexane/EtOAc 3:1) in 43.7 mg (0.12 mmol, 12%) yield as a colorless solid. R_f = 0.29 (*n*-hexane/EtOAc 3:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.56−7.47 (m, 2H), 7.39−7.29 (m, 3H), 5.64 (s, 1H), 5.09 (dd, *J* = 3.7, 1.6 Hz, 1H), 4.63 (d, *J* = 1.6 Hz, 1H), 4.23 (dd, *J* = 9.5, 4.1 Hz, 1H), 4.11 (dd, *J* = 10.0, 3.7 Hz, 1H), 3.91 (t, *J* = 9.4 Hz, 1H), 3.87−3.72 (m, 2H), 3.41 (s, 3H), 2.67 (hept, *J* = 6.9 Hz, 1H), 1.21 (d, *J* = 7.0 Hz, 7H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 178.0, 139.2, 129.9, 129.0, 127.5, 103.4, 101.0, 80.3, 73.8, 69.8, 68.0, 65.0, 55.6, 35.2, 19.4, 19.2 ppm. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{18}H_{24}O_7Na$, 375.1414; found, 375.1415 IR (ATR) ν/cm^{-1}: 3468, 2974, 2935, 1736, 1456, 1386, 1316, 1255, 1199, 1158, 1130, 1097, 1069, 1026, 969, 924, 883, 795, 751, 699.

*Methyl 3-O-Isobutyryl-4,6-O-benzylidene-α,D-mannopyranoside (**18b**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (206 mg, 217 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **18b** after column chromatography (*n*-hexane/EtOAc 3:1) in 207.0 mg (0.59 mmol, 59%) yield as a colorless solid. R_f = 0.12 (*n*-hexane/EtOAc 3:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.46−7.39 (m, 2H), 7.37−7.28 (m, 3H), 5.60 (s, 1H), 5.16 (dd, *J* = 10.4, 3.4 Hz, 1H), 4.68 (d, *J* = 1.7 Hz, 1H), 4.26−4.20 (m, 1H), 4.18−4.10 (m, 1H), 4.03 (dd, *J* = 3.5, 1.7 Hz, 1H), 3.90−3.78 (m, 2H), 3.42 (s, 3H), 2.62 (hept, *J* = 7.0 Hz, 1H), 1.15 (dd, *J* = 7.0, 4.6 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 178.3, 139.1, 129.9, 129.0, 127.3, 103.8, 103.1, 77.5, 72.0, 70.3, 69.8, 65.3, 55.4, 35.2, 19.5, 19.1 ppm. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{18}H_{24}O_7Na$, 375.1414; found, 375.1416 IR (ATR) ν/cm^{-1}: 3521, 2968, 2932, 1721, 1469, 1451, 1369, 1317, 1205, 1161, 1119, 1097, 1060, 1024, 970, 911, 800, 747, 697.

*Methyl 2,3-O-Isobutyryl-4,6-O-benzylidene-α,D-mannopyranoside (**18c**). Procedure 1.* Methyl 4,6-*O*-benzylidene-α,D-mannopyranoside (282.0 mg, 1.0 mmol, 1.0 equiv), DMAP (12.2 mg, 0.1 mmol, 0.1 equiv), isobutyric anhydride (206 mg, 217 μL, 1.3 mmol, 1.3 equiv), and 10 mL of DCM were used to obtain **18c** after column chromatography (*n*-hexane/EtOAc 3:1) in 125.0 mg (0.29 mmol, 29%) yield as a colorless solid. R_f = 0.45 (*n*-hexane/EtOAc 3:1). ^{1}H NMR (400 MHz, MeOH-d_4): δ 7.49−7.40 (m, 2H), 7.40−7.32 (m, 3H), 5.67 (s, 1H), 5.36−5.29 (m, 2H), 4.71 (s, 1H), 4.33−4.24 (m, 1H), 4.16−4.07 (m, 1H), 3.95−3.85 (m, 2H), 3.46 (s, 3H), 2.69 (hept, *J* = 6.9 Hz, 1H), 2.50 (hept, *J* = 7.0 Hz, 1H), 1.24 (dd, *J* = 14.2, 7.0 Hz, 6H), 1.11 (dd, *J* = 7.0, 1.5 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, MeOH-d_4): δ 177.6, 177.3, 138.9, 130.0, 129.1, 127.3, 103.1, 101.1, 77.7, 70.9, 70.0, 69.7, 65.2, 55.6, 35.2, 19.5, 19.2, 19.2, 19.1 ppm. HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{22}H_{30}O_8Na$, 445.1833; found, 445.1834 IR (ATR) ν/cm^{-1}: 2975, 2936, 1741, 1469, 1387, 1283, 1251, 1195, 1128, 1073, 1012, 967, 914, 892, 750, 698.

Catalysts. *Boc-L-Pmh-^{A}Gly-L-Cha-L-Phe-OMe (**1**).* The synthesis and characterization data for **1** can be found in the literature.[16]

*Boc-D-Pmh-^{A}Gly-L-Val-L-Phe-OMe (**2**). Procedure 2.* The coupling of H-L-Phe-OMe·HCl and Boc-L-Val-OH was performed on a 5.0 mmol scale to obtain 1.90 g (5.0 mmol, quant.) of Boc-L-Val-L-Phe-OMe as a colorless solid. Procedure 3: 5.0 mmol of Boc-L-Val-L-Phe-OMe was deprotected and directly used for the next coupling. Procedure 2: The coupling of H-L-Val-L-Phe-OMe·HCl and Boc-^{A}Gly-OH was performed on a 5.0 mmol scale to obtain 2.83 g (5.0 mmol, quant.) of Boc-^{A}Gly-L-Val-L-Phe-OMe as a colorless solid. Procedure 3: 2.1 mmol Boc-^{A}Gly-L-Val-L-Phe-OMe was deprotected and directly used for the next coupling. Procedure 4: The coupling of H-^{A}Gly-L-Val-L-Phe-OMe·HCl and Boc-D-Pmh-OH was performed on a 2.1 mmol scale to obtain 0.82 g (1.16 mmol, 55%) of **2** after column chromatography (CH_2Cl_2/MeOH 10:1) as a colorless solid. R_f = 0.38. (CH_2Cl_2/MeOH 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30 (s, 1H), 7.23−7.12 (m, 3H), 7.09−7.04 (m, 2H), 6.90 (d, *J* = 7.9 Hz, 1H), 6.76 (s, 1H), 6.39 (s, 1H), 6.23 (d, *J* = 8.5 Hz, 1H), 5.29 (d, *J* = 8.5 Hz, 1H), 4.76 (td, *J* = 7.5, 5.8 Hz, 1H), 4.23 (dd, *J* = 8.5, 6.4 Hz, 2H), 3.62 (s, 3H), 3.44 (s, 3H), 3.09 (dd, *J* = 14.0, 5.9 Hz, 1H), 2.98 (dd, *J* = 14.0, 7.4 Hz, 1H), 2.90 (d, *J* = 6.8 Hz, 2H), 2.21−2.04 (m, 4H), 2.01−1.80 (m, 2H), 1.77−1.49 (m, 9H), 1.35 (s, 9H), 0.80 (t, *J* = 7.1 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 176.4, 171.8, 171.2, 169.8, 155.5, 138.2, 136.1, 129.2, 128.8, 128.8, 128.5, 127.2, 80.4, 57.7, 54.2, 53.6, 53.4, 52.4, 52.4, 42.8, 40.1, 38.7, 38.2, 37.8, 35.2, 31.8, 31.5, 29.3, 29.2, 28.4, 27.5, 19.2, 18.2 ppm.[17d]

*Boc-L-Pmh-OMe (**15**).* The synthesis and characterization data for **15** can be found in the literature.[17d]

*H-^{A}Gly-OMe·HCl (**19**).* 6 mL of dry methanol was cooled to 0 °C, and thionyl chloride (0.83 g, 0.50 mL, 7.0 mmol, 3.5 equiv) was added. The solution was stirred at 0 °C for 30 min, then Boc-^{A}Gly-

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OH (0.59 g, 2.0 mmol, 1.0 equiv) was added. The solution was stirred at rt for 20 h. The solvent was removed under reduced pressure to afford **19** in 0.49 g (2.0 mmol, quant.) yield as a colorless solid. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.46 (s, 3H), 3.63 (s, 3H), 2.31−2.23 (m, 2H), 2.18 (s, 2H), 2.08−1.96 (m, 4H), 1.92−1.77 (m, 4H), 1.73−1.60 (m, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 175.9, 53.2, 52.0, 42.6, 41.5, 39.7, 37.3, 34.4, 28.8 ppm.[46]

*Boc-L-Pmh-^{A}Gly-OMe (**16**). Procedure 4.* The coupling of H-^{A}Gly-OMe·HCl and Boc-L-Pmh-OH was performed on a 0.20 mmol scale to obtain 0.049 g (0.11 mmol, 53%) of **16** after column chromatography (CH_2Cl_2/MeOH 10:1) as a colorless solid. R_f = 0.31 (CH_2Cl_2/MeOH 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.46 (s, 1H), 6.80 (2, 1H), 5.90 (s, 1H), 5.20 (d, J = 8.2 Hz, 1H), 4.16−4.05 (m, 1H), 3.58 (s, 3H), 3.56 (s, 3H), 2.93 (d, J = 6.8 Hz, 2H), 2.14−2.08 (m, 2H), 2.06−1.96 (m, 2H), 1.91−1.69 (m, 8H), 1.61−1.52 (m, 2H), 1.37 (s, 9H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 176.9, 169.7, 155.5, 138.1, 127.8, 127.4, 80.6, 52.4, 51.9, 42.7, 42.2, 40.6, 40.5, 37.9, 35.3, 31.9, 29.1, 28.4, 27.0 ppm. HRMS (ESI-TOF) m/z: [M + H]$^+$ calcd for $C_{24}H_{36}N_4O_5H$, 461.2758; found, 461.2762, [M + Na]$^+$ calcd for $C_{24}H_{36}N_4O_5Na$, 483.2578; found, 483.2580. IR (ATR) ν/cm^{-1}: 3308, 2911, 2857, 1796, 1712, 1661, 1506, 1454, 1391, 1365, 1343, 1241, 1164, 1125, 1106, 1050, 977, 928, 856, 833, 771, 662.

*Boc-L-Pmh-^{A}Gly-L-Cha-OMe (**17**). Procedure 2.* The coupling of H-L-Cha-OMe·HCl and Boc-^{A}Gly-OH was performed on a 0.50 mmol scale to obtain 0.26 g (0.50 mmol, quant.) of Boc-L-Cha-^{A}Gly-OMe as a colorless solid. Procedure 3: 0.50 mmol of Boc-L-Cha-^{A}Gly-OMe was deprotected and directly used for the next coupling. Procedure 4: The coupling of H-L-Cha-^{A}Gly-OMe·HCl and Boc-L-Pmh-OH was performed on a 0.50 mmol scale to obtain 0.12 g (0.19 mmol, 38%) of **17** after column chromatography (CH_2Cl_2/MeOH 10:1) as a colorless solid. R_f = 0.35 (CH_2Cl_2/MeOH 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75 (s, 1H), 6.93 (s, 1H), 6.22 (s, 1H), 6.00 (d, J = 8.2 Hz, 1H), 5.34 (d, J = 8.3 Hz, 1H), 4.62 (td, J = 8.7, 5.5 Hz, 1H), 4.31−4.19 (m, 1H), 3.72 (s, 3H), 3.68 (s, 3H), 3.01 (d, J = 6.8 Hz, 2H), 2.26−2.16 (m, 2H), 2.10−2.00 (m, 2H), 2.00−1.86 (m, 4H), 1.86−1.57 (m, 12H), 1.53 (ddd, J = 14.2, 9.0, 5.9 Hz, 1H), 1.43 (s, 9H), 1.29−1.10 (m, 4H), 1.01−0.82 (m, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 176.3, 173.9, 169.6, 137.5, 128.2, 80.4, 52.5, 52.3, 49.9, 42.5, 42.2, 40.4, 40.0, 38.2, 38.1, 35.2, 34.3, 33.4, 32.6, 32.1, 29.1, 29.1, 28.3, 27.1, 26.4, 26.2, 26.0 ppm. HRMS (ESI-TOF) m/z: [M + H]$^+$ calcd for $C_{33}H_{51}N_5O_6H$, 614.3912; found, 614.3904, [M + Na]$^+$ calcd for $C_{33}H_{51}N_5O_6Na$, 636.3732; found, 636.3730. IR (ATR) ν/cm^{-1}: 3307, 2924, 2851, 1795, 1699, 1507, 1450, 1389, 1377, 1286, 1255, 1229, 1179, 1166, 1146, 1081, 976, 947, 928, 912, 899, 855, 834, 768, 753, 733, 718, 667.

*Boc-D-Pmh-OMe (**20**). Procedure 4.* The esterification of methanol and Boc-D-Pmh-OH was performed on a 2.0 mmol scale to obtain 0.42 g (1.5 mmol, 75%) of **20** after column chromatography (CH_2Cl_2/MeOH 10:1) as a colorless solid. R_f = 0.40 (CH_2Cl_2/MeOH 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.43 (s, 1H), 6.78 (s, 1H), 5.20 (d, J = 7.8 Hz, 1H), 4.53 (q, J = 6.4 Hz, 1H), 3.73 (s, 3H), 3.58 (s, 3H), 3.09 (qd, J = 15.4, 5.9 Hz, 2H), 1.41 (s, 9H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 171.8, 154.7, 140.0, 129.6, 126.7, 80.4, 53.1, 52.7, 31.5, 28.9, 27.0 ppm. HRMS (ESI-TOF) m/z: [M + H]$^+$ calcd for $C_{13}H_{21}N_3O_4H$, 284.1605; found, 284.1600, [M + Na]$^+$ calcd for $C_{13}H_{21}N_3O_4Na$, 306.1424; found, 306.1423. IR (ATR) ν/cm^{-1}: 3155, 2979, 2011, 1733, 1694, 1535, 1509, 1451, 1437, 1420, 1390, 1365, 1322, 1289, 1258, 1243, 1219, 1200, 1163, 1110, 1073, 1053, 1038, 990, 934, 814, 752, 663.

*Boc-^{A}Gly-L-Pmh-OMe (**21**).* The synthesis and characterization data for **21** can be found in the literature.[24]

*3,5-(Bis(trifluoromethyl)phenyl)thiourea-^{A}Gly-L-Pmh-OMe (**22**).* The synthesis and characterization data for **22** can be found in the literature.[24]

*Boc-D-Val-^{A}Gly-L-Pmh-OMe (**23**).* The synthesis and characterization data for **23** can be found in the literature.[24]

*Boc-L-Cha-^{A}Gly-L-Pmh-OMe (**24**).* The synthesis and characterization data for **24** can be found in the literature.[24]

*Boc-L-Trp-^{A}Gly-L-Pmh-OMe (**25**).* The synthesis and characterization data for **25** can be found in the literature.[24]

*Boc-L-Phe-^{A}Gly-L-Pmh-OMe (**26**).* The synthesis and characterization data for **26** can be found in the literature.[24]

*Boc-D-Pmh-^{A}Gly-OMe (**27**). Procedure 4.* The coupling of H-^{A}Gly-OMe·HCl and Boc-D-Pmh-OH was performed on a 0.20 mmol scale to obtain 0.056 g (0.12 mmol, 61%) of **27** after column chromatography (CH_2Cl_2/MeOH 10:1) as a colorless solid. R_f = 0.33 (CH_2Cl_2/MeOH 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.35 (s, 1H), 6.78 (s, 1H), 5.78 (s, 1H), 5.18 (d, J = 8.3 Hz, 1H), 4.15−4.02 (m, 1H), 3.58 (s, 3H), 3.54 (s, 3H), 2.98−2.86 (m, 2H), 2.08−2.13 (m, 2H), 2.07−1.95 (m, 2H), 1.90−1.66 (m, 8H), 1.53−1.57 (m, 2H), 1.37 (s, 9H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 176.9, 169.8, 155.5, 138.4, 128.3, 127.4, 80.5, 54.6, 52.3, 51.9, 42.6, 42.2, 40.6, 40.5, 37.9, 35.3, 31.7, 29.1, 28.4, 26.9 ppm. HRMS (ESI-TOF) m/z: [M + H]$^+$ calcd for $C_{24}H_{36}N_4O_5H$, 461.2758; found, 461.2761, [M + Na]$^+$ calcd for $C_{24}H_{36}N_4O_5Na$, 483.2578; found, 483.2575. IR (ATR) ν/cm^{-1}: 3305, 2912, 2858, 1711, 1661, 1505, 1454, 1435, 1391, 1365, 1342, 1320, 1239, 1164, 1124, 1105, 1053, 929, 873, 816, 778, 757, 661.

*Boc-L-Pmh-^{A}Gly-L-Val-OMe (**28**). Procedure 2.* The coupling of H-L-Val-OMe·HCl and Boc-^{A}Gly-OH was performed on a 0.30 mmol scale to obtain 0.13 g (0.30 mmol, quant.) of Boc-^{A}Gly-L-Val-OMe as a colorless solid. Procedure 3: 0.30 mmol Boc-^{A}Gly-L-Val-OMe was deprotected and directly used for the next coupling. Procedure 4: The coupling of H-^{A}Gly-L-Val-OMe·HCl and Boc-L-Pmh-OH was performed on a 0.30 mmol scale to obtain 0.064 g (0.12 mmol, 40%) of **28** after column chromatography (CH_2Cl_2/MeOH 10:1) as a colorless solid. R_f = 0.25 (CH_2Cl_2/MeOH 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56 (s, 1H), 6.87 (s, 1H), 6.07 (d, J = 8.5 Hz, 1H), 6.01 (s, 1H), 5.27 (d, J = 8.2 Hz, 1H), 4.53 (dd, J = 8.6, 5.0 Hz, 1H), 4.25−4.14 (m, 1H), 3.73 (s, 3H), 3.63 (s, 3H), 3.05−2.94 (m, 2H), 2.25−2.18 (m, 2H), 2.18−2.09 (m, 1H), 2.03 (s, 2H), 1.99−1.74 (m, 8H), 1.71−1.56 (m, 2H), 1.43 (s, 9H), 0.90 (t, J = 6.9 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 176.4, 172.9, 169.7, 155.0, 138.1, 127.8, 127.3, 80.6, 56.8, 52.5, 52.3, 42.9, 42.5, 40.5, 40.4, 38.4, 38.3, 35.3, 31.9, 31.5, 29.3, 28.4, 27.0, 19.1, 18.1 ppm. HRMS (ESI-TOF) m/z: [M + H]$^+$ calcd for $C_{29}H_{45}N_5O_6H$, 560.3443; found, 560.3443, [M + Na]$^+$ calcd for $C_{29}H_{45}N_5O_6Na$, 582.3262; found, 582.3261. IR (ATR) ν/cm^{-1}: 3308, 2910, 2855, 1795, 1699, 1652, 1506, 1453, 1390, 1365, 1286, 1248, 1230, 1165, 1110, 1082, 976, 928, 855, 833, 768, 664.

*Boc-D-Pmh-^{A}Gly-L-Val-OMe (**29**). Procedure 2.* The coupling of H-L-Val-OMe·HCl and Boc-^{A}Gly-OH was performed on a 0.30 mmol scale to obtain 0.13 g (0.30 mmol, quant.) of Boc-^{A}Gly-L-Val-OMe as a colorless solid. Procedure 3: 0.30 mmol Boc-^{A}Gly-L-Val-OMe was deprotected and directly used for the next coupling. Procedure 4: The coupling of H-^{A}Gly-L-Val-OMe·HCl and Boc-D-Pmh-OH was performed on a 0.30 mmol scale to obtain 0.059 g (0.11 mmol, 35%) of **29** after column chromatography (CH_2Cl_2/MeOH 10:1) as a colorless solid. R_f = 0.25 (CH_2Cl_2/MeOH 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54 (s, 1H), 6.86 (s, 1H), 6.07 (d, J = 8.6 Hz, 1H), 5.99 (s, 1H), 5.26 (d, J = 8.3 Hz, 1H), 4.53 (dd, J = 8.5, 5.0 Hz, 1H), 4.25−4.14 (m, 1H), 3.73 (s, 3H), 3.62 (s, 3H), 3.05−2.94 (m, 2H), 2.24−2.18 (m, 2H), 2.18−2.09 (m, 1H), 2.06−1.99 (m, 2H), 1.97−1.75 (m, 8H), 1.69−1.57 (m, 2H), 1.42 (s, 9H), 0.90 (t, J = 6.9 Hz, 6H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 176.4, 172.9, 169.8, 155.5, 138.1, 127.8, 127.4, 80.6, 56.8, 52.5, 52.3, 42.8, 42.5, 40.5, 40.5, 38.4, 38.3, 35.3, 31.9, 31.5, 29.3, 28.4, 27.0, 19.1, 18.1 ppm. HRMS (ESI-TOF) m/z: [M + H]$^+$ calcd for $C_{29}H_{45}N_5O_6H$, 560.3443; found, 560.3445, [M + Na]$^+$ calcd for $C_{29}H_{45}N_5O_6Na$, 582.3262; found, 582.3256. IR (ATR) ν/cm^{-1}: 3307, 2911, 2857, 1652, 1506, 1454, 1391, 1365, 1245, 1207, 1162, 1110, 1050, 1020, 929, 815, 661.

*Boc-L-Pmh-^{A}Gly-L-Phe-OMe (**30**).* The synthesis and characterization data for **S13** can be found in the literature.[22]

*Boc-D-Pmh-^{A}Gly-L-Cha-L-Phe-OMe (**31**). Procedure 2.* The coupling of H-L-Phe-OMe·HCl and Boc-L-Cha-OH·DCHA was performed on a 0.82 mmol scale to obtain 0.29 g (0.66 mmol, 80%) of Boc-L-Cha-L-Phe-OMe as a colorless solid. Procedure 3: 0.66 mmol of Boc-L-Cha-L-Phe-OMe was deprotected and directly used for the next

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coupling. Procedure 2: The coupling of H-L-Cha-L-Phe-OMe·HCl and Boc-^{A}Gly-OH was performed on a 0.66 mmol scale to obtain 0.40 g (0.65 mmol, 99%) of Boc-^{A}Gly-L-Cha-L-Phe-OMe as a colorless solid. Procedure 3: 0.65 mmol Boc-^{A}Gly-L-Cha-L-Phe-OMe was deprotected and directly used for the next coupling. Procedure 4: The coupling of H-^{A}Gly-L-Cha-L-Phe-OMe·HCl and Boc-D-Pmh-OH was performed on a 0.65 mmol scale to obtain 0.29 g (0.38 mmol, 59%) of **31** after column chromatography (CH_2Cl_2/MeOH 10:1) as a colorless solid. R_f = 0.42. (CH_2Cl_2/MeOH 10:1). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38 (s, 1H), 7.30−7.19 (m, 3H), 7.13−7.08 (m, 2H), 6.83 (s, 1H), 6.77 (d, J = 7.9 Hz, 1H), 6.13−6.02 (m, 2H), 5.27 (d, J = 8.4 Hz, 1H), 4.83−4.75 (m, 1H), 4.47 (td, J = 8.3, 6.2 Hz, 1H), 4.26−4.14 (m, 1H), 3.69 (s, 3H), 3.54 (s, 3H), 3.13 (dd, J = 14.0, 5.8 Hz, 1H), 3.04 (dd, J = 14.0, 6.9 Hz, 1H), 2.96 (d, J = 6.9 Hz, 2H), 2.22−2.16 (m, 2H), 2.03−1.93 (m, 3H), 1.93−1.80 (m, 3H), 1.77−1.55 (m, 12H), 1.49−1.39 (m, 1H), 1.41 (s, 9H), 1.28−1.06 (m, 4H), 0.96−0.77 (m, 2H) ppm. ^{13}C{^{1}H} NMR (100 MHz, $CDCl_3$): δ 176.4, 172.1, 171.8, 169.8, 155.5, 138.3, 136.1, 129.3, 128.7, 128.4, 127.3, 127.2, 80.5, 53.4, 52.5, 52.4, 50.8, 42.7, 42.5, 40.4, 40.3, 39.9, 38.4, 38.2, 37.9, 35.3, 34.3, 33.6, 32.9, 31.6, 29.3, 29.2, 28.5, 28.5, 27.2, 26.5, 26.3, 26.2 ppm. HRMS (ESI-TOF) m/z: [M + H]$^+$ calcd for $C_{42}H_{60}N_6O_7H$, 761.4596; found, 761.4594, [M + Na]$^+$ calcd for $C_{42}H_{60}N_6O_7Na$, 783.4416; found, 783.4418. IR (ATR) ν/cm^{-1}: 3298, 2918, 2852, 1745, 1659, 1505, 1449, 1391, 1365, 1282, 1245, 1215, 1166, 1110, 1050, 1021, 929, 890, 814, 747, 700, 670, 665, 542, 495, 439.

*Boc-L-Pmh-^{A}Gly-L-Val-L-Phe-OMe (**32**).* The synthesis and characterization data for **32** can be found in the literature.[15]

*Boc-D-Pmh-^{A}Gly-D-Val-L-Phe-OMe (**33**).* The synthesis and characterization data for **33** can be found in the literature.[17d]

*Boc-L-Pmh-^{A}Gly-^{A}Gly-L-Phe-OMe (**34**).* The synthesis and characterization data for **34** can be found in the literature.[15]

*Methyl 4,6-O-Benzylidene-α-D-glucopyranoside (**3**).* 194.2 mg (1.00 mmol, 1.00 equiv) of methyl α-D-glucopyranoside, 152.2 mg (150.7 μL, 1.00 mmol, 1.00 equiv) of benzaldehyde dimethyl acetal, 0.3 mg (0.001 mmol, 0.001 equiv) of camphor sulfonic acid, and 5000 mg 4 Å were suspended in 100 mL of dry toluene and refluxed for 3 h. It was then filtered and concentrated under reduced pressure. The crude product was purified via column chromatography (EtOAc) to obtain 68.2 mg (0.24 mmol, 24%) of product as a colorless solid. R_f = 0.30 (EtOAc).

Procedure for the One-Pot Protection and Acetylation. 194.2 mg (1.00 mmol, 1.00 equiv) of methyl α-D-glucopyranoside, 152.2 mg (150.7 μL, 1.00 mmol, 1.00 equiv) of benzaldehyde dimethyl acetal, 0.3 mg (0.001 mmol, 0.001 equiv) of camphor sulfonic acid, and 5000 mg 4 Å were suspended in 100 mL of dry toluene and refluxed for 3 h. After cooling to rt, 35.5 mg (0.05 mmol, 0.05 equiv) of peptide catalyst **2** and 132.7 mg (122.9 μL, 1.30 mmol, 1.3 equiv) of acetic anhydride were added and stirred for 18 h. It was then filtered, quenched with 1 mL methanol, and concentrated under reduced pressure. The crude product was purified via column chromatography (*n*-hexane/EtOAc 4:1 → 1:1) to obtain 15.3 mg (0.04 mmol, 4%) of **3c**, 70.0 mg (0.22 mmol, 22%) of **3a**, and 16.8 mg (0.05 mmol, 5%) of **3b**.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.joc.0c02772.

Additional results, superimposed ^{1}H NMR spectra, catalyst screening and DoE, and NMR spectra of all compounds (PDF)

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Notes

The authors declare no competing financial interest.

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