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A One-Pot, Copper-Catalyzed Cascade Route to 2-Indolyl-C-glycosides

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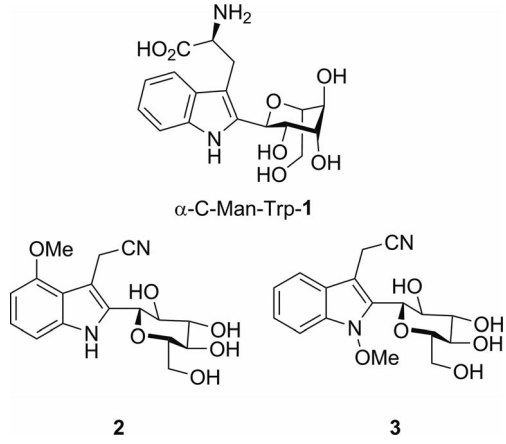
Dedicated to Professor G. S. R. Subba Rao on the occasion of his 75th birthday

Keywords: Carbohydrates / C-glycosides / Nitrogen heterocycles / Alkynes / Copper / Domino reactions

An efficient and high-yielding, one-pot, Cu-catalyzed synthesis of 2-indolyl-C-glycosides is delineated. The sequence involves a cascade Sonogashira type coupling and a hydroamination reaction between sugar-derived alkynes and *N*-tosyl-*o*-iodoaniline followed by removal of the *N*-tosyl group to provide a library of 2-indolyl-C-glycosides in moderate to excellent yields.

Introduction

The C-aryl glycosides[1] constitute an important class of C-glycosides, and comprise a large number of biologically active natural products that have an aromatic ring linked to the anomeric carbon of a sugar through a C–C bond. When a nitrogen heterocycle is attached to the anomeric carbon of the sugar through a C–C bond, it leads to another interesting class of C-glycosides[2] that display potent antiviral and anticancer activities due to their structural similarity to the naturally-occurring N-nucleosides. 2-Indolyl-C-glycosides (Scheme 1) represent one such class of C-glycosides with a heteroaryl aglycon, exhibiting interesting biological activities.[3]



Scheme 1. Proposed structures of 2-indolyl-C-glycosides **2** and **3** from *Isatis indigotica*.

Although several methods are available for the synthesis of 2-indole derivatives,[4] there are only a handful of reports on the synthesis of 2- and 3-indolyl-C-glycosides, which mostly involve the addition of *N*-protected lithio-indoles onto sugar-derived lactones or lactols followed by reduction or cyclization.[5] Recently, as a part of their synthetic studies on α-C-mannosyltryptophan,[6] Nishikawa and co-workers reported a three-step protocol for the construction of 2-indolyl-C-glycosides[7] that involves a Pd-mediated Sonogashira coupling of sugar-derived alkynes with *N*-tosyl-*o*-iodoaniline, a Cu-mediated Castro cyclization, and subsequent tetrabutylammonium fluoride (TBAF)-assisted cleavage of the *N*-tosyl group (Scheme 2). Although this protocol serves as a general method for the synthesis of a variety of 2-indolyl-C-glycosides, it requires three individual steps to construct the indole skeleton. As part of our ongoing interest in the synthesis of C-aryl glycosides[8] and also in view of the biological importance of 2-indolyl-C-glycosides, herein, we report a mild, inexpensive, Cu^{I}-catalyzed one-pot synthesis of 2-indolyl-C-glycosides from *N*-tosyl-iodoaniline and various ethynyl C-glycosides. This method employs a domino C–C bond formation to internal alkynes followed by a hydroamination/annulation reaction and TBAF-mediated *N*-tosyl deprotection. During the course of our preliminary studies on this work, Kotora and co-workers[9] reported a Pd-catalyzed, two-step methodology for the construction of 2-indolyl-C-glycosides that involves a Pd-mediated Sonogashira coupling, followed by a Pd-catalyzed hydroamination/cyclization (Scheme 2). This protocol also requires a couple of steps for the construction of the indole framework, and use of the costly JohnPhos ligand was imperative for the hydroamination.

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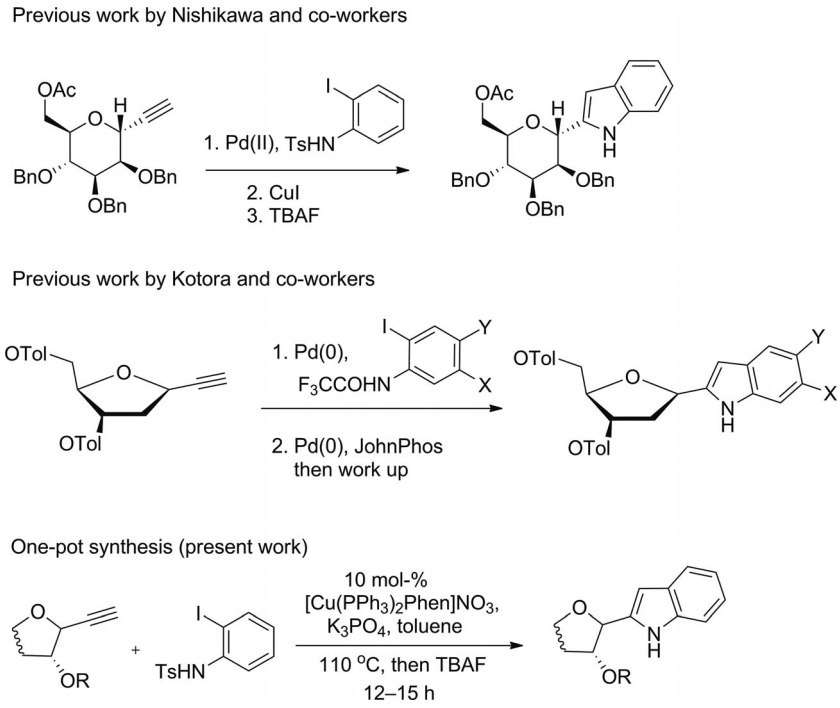
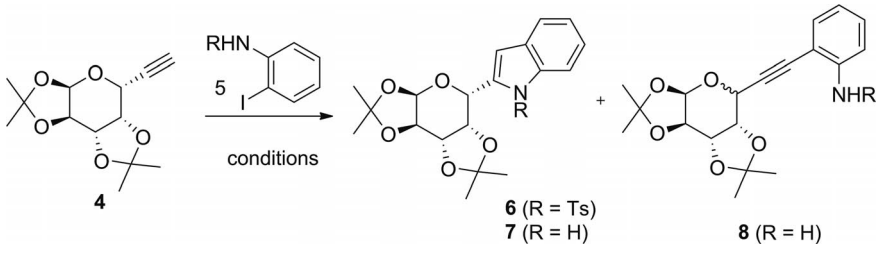


Scheme 2.

To test the premise, we selected galactose-derived alkyne **4**[8a] and 2-iodoaniline **5** (R = H) as our model substrates to identify suitable reaction conditions for the one-pot synthesis of 2-indolyl-C-glycosides. To our surprise, all attempts to perform the reaction under various Pd-catalyzed reaction conditions[10] failed (Scheme 3, Table 1) and, instead, led to the formation of an intractable mixture from which even traces of the desired product could not be identified (entries 1–4). We then turned our attention to the one-pot reaction conditions reported by Oskooie, Heravi and co-workers[11] for the synthesis of 2-phenyl indoles. Under these conditions, the reaction proceeded smoothly but stopped at the Sonogashira-coupled product **8** (R = H) with concomitant partial epimerization at the glycosidic center (87%, *dr* 3:1) (entry 5). These results substantiate the requirement for an electron-withdrawing group on the nitrogen atom for the concomitant annulation by enhancing the acidity of NH in *N*-tosyl-*o*-iodoaniline **5** (R = Ts). Thus, the reaction of N-tosylated *o*-iodoaniline **5** (R = Ts) with galactose-derived alkyne **4** under Larock's conditions[12] (entry 6) was attempted. Although it was heartening to see the formation of the desired product, *N*-tosyl-2-indolyl-C-galactoside **6** (R = Ts), the yield (18%) was far from satisfactory. Nevertheless, encouraged by the formation of the desired product, we then optimized the reaction conditions to improve the yield. Thus, this reaction was attempted under Microwave irradiation conditions,[10b] which led to a significant improvement in the yield of the reaction, affording the required product in modest yield (55%; entry 7). In our efforts to optimize the reaction conditions further, we next looked at copper-based catalysts and chose the Venkataraman catalyst[13a] $[Cu(Phen)(PPh_3)_2]NO_3$, which has been successfully used in one-pot syntheses of benzofurans and 2-indole derivatives from 2-iodophenol and 2-iodoaniline, respectively, by the group of Venkataraman[13] and Cacchi.[14]

When we attempted the reaction of **4** with 2-iodoaniline under the reported conditions (entry 8), only the Sonogashira type coupling product **8** (R = H) (67%), with partial epimerization at the glycosidic center (*dr* 1.75:1) (entry 8), was obtained. This observation further underlines the importance of having an electron-withdrawing group on the



Scheme 3. Cascade synthesis of 2-indolyl-C-glycosides.

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Table 1. Reaction optimization for the synthesis of galactose derived *N*-tosyl-2-indolyl-C-glycoside **6** (R = Ts) from galactose derived alkyne **4** and *N*-tosyl-iodoaniline **5**.

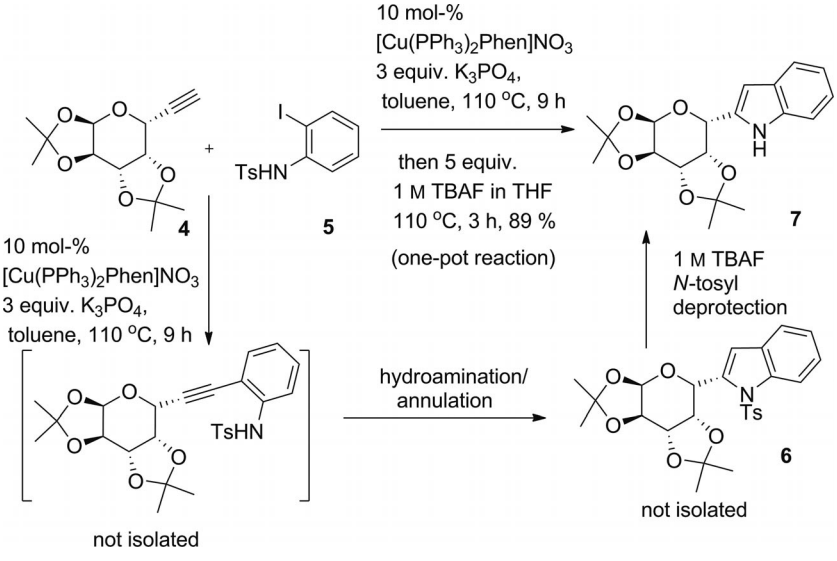
Enty	R	Reaction conditions	Yield of **6** (%)[a]	Yield of **8** (%)[a]
1	H	$Pd(OAc)_2$, PPh_3, K_2CO_3, LiCl, DMF	–	–
2	H	$Pd(OAc)_2$, PPh_3, K_2CO_3, Bu_4NBr, DMF	–	–
3	H	$Pd(OAc)_2$, Et_3N, NMP	–	–
4	H	$PdCl_2$, Na_2CO_3, LiCl, DMF	–	–
5	H	$Pd(PPh_3)_2Cl_2$, CuI, Et_3N, DMF	–	87 (3:1)[b]
6	Ts	$Pd(OAc)_2$, PPh_3, nBu_4NBr, Na_2CO_3, DMF	18	–
7	Ts	$Pd(OAc)_2$, Et_3N, NMP, MW (100 W, 125 °C)	55	–
8	H	$[Cu(PPh_3)_2phen]NO_3$, Cs_2CO_3, 110 °C, toluene, then *t*BuONa	–	67 (1.75:1)[b]
9	Ts	$[Cu(PPh_3)_2phen]NO_3$, K_3PO_4, 110 °C, toluene	83	–

[a] Isolated yield. [b] Diastereomeric ratio given in parentheses.

nitrogen atom to facilitate the subsequent cyclative-hydroamination through effective stabilization of the η2 amine-acetylene-Cu complex. Thus, after extensive optimization with *N*-tosyl-2-iodoaniline **5** (R = Ts), we were pleased to find exclusive formation of the desired *N*-tosyl-2-indolyl-C-galactoside **6** (R = Ts) (entry 9) in excellent yield (83%) in the presence of $[Cu(Phen)(PPh_3)_2]NO_3$ (10 mol-%) catalyst and K_3PO_4 after heating at reflux in toluene.

Although our primary aim was to realize the synthesis of 2-indolyl-C-glycosides without amine protection through a cascade reaction, the requirement for an electron-withdrawing group (Ts) proved to be crucial (see above). Therefore, we sought to remove the temporary masking group (Ts) in the same pot upon formation of the indole skeleton through the addition of an external reagent. In our search for compatible conditions to cleave the *N*-tosyl group, we found TBAF-mediated removal to be suitable.[15] Thus, the one-pot cascade reaction of alkyne **4** and **5** (R = Ts) in the presence of 10 mol-% $[Cu(Phen)(PPh_3)_2]NO_3$ and K_3PO_4 (3 equiv.) at 110 °C provided *N*-tosyl-2-indolyl-C-glycoside **6**, and subsequent addition of TBAF (5 equiv.) at 110 °C promoted the formation of the desired 2-indolyl-C-galactoside **7** in 89% yield (Scheme 4). It should be noted that the above one-pot reaction involves three sequential transformations: the Sonogashira-type coupling, cyclative-hydroamination, and TBAF-mediated removal of *N*-Ts group.

These optimized procedures were then applied to a variety of sugar-derived alkynes **4a**–**i** in combination with *N*-tosyl-iodoaniline **5** (R = Ts) to generate a library of 2-indolyl-C-glycosides **7a**–**i** (Table 2, R = H) through a one-pot reaction. In a similar way, *N*-tosyl-2-indolyl-C-glycosides **6a**–**i** were also synthesized from alkynes **4a**–**i** in the absence of TBAF (Table 2, R = Ts). Thus, D-glucose-derived alkyne **4a**,[8a] under the optimized one-pot conditions, afforded 2-indolyl-C-glycoside **7a** in excellent yield (81%). Similarly, D-glucose-derived alkyne **4b** with a free hydroxy group was also found to be compatible with these conditions, affording the required product **7b** in 90% yield. It is noteworthy that the free hydroxy group was unaffected under these reaction conditions. Furthermore, D-ribose-derived alkynes **4c**–**f** furnished the corresponding 2-indolyl-C-glycoside **7c**–**f** in good yields. In the case of alkyne **4d**, the required glycoside product **7d** was obtained in 83% yield accompanied by concomitant cleavage of the TBS group, as anticipated. The diastereomeric mixture of ribose-derived propargyl alkyne **4e** (α,β; 2.4:1) afforded the desilylated product α-**7e** in 67% yield as the major product, and the minor product, 2-indolyl-C-β-glycoside β-**7e**, was isolable from the other impurities. However, in the absence of TBAF, glycosides α-**6e** and β-**6e** were obtained in an approximate 2:1 ratio in favor of the former. Moreover, the



Scheme 4. One-pot synthesis of 2-indolyl-C-glycosides.

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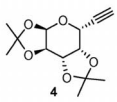
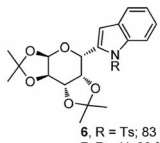
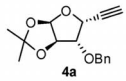
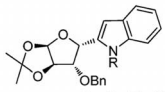
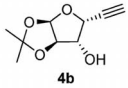
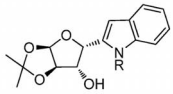
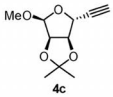
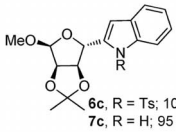
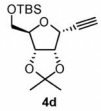
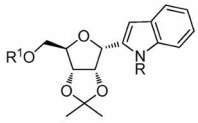
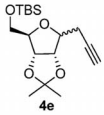
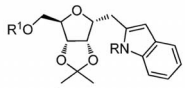
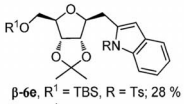
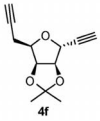
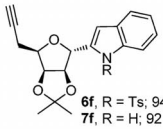
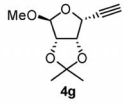
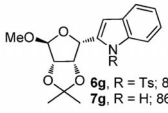
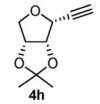
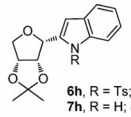
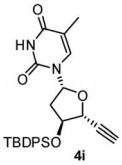
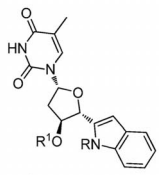
Table 2. Cu(I)-catalyzed synthesis of 2-indolyl-C-glycosides.

Entry	1-Ethynyl glycosides	2-Indolyl-C-glycosides (isolated yield %)
1	 **4**	 **6**, R = Ts; 83 % **7**, R = H; 89 %
2	 **4a**	 **6a**, R = Ts; 98 % **7a**, R = H; 81 %
3	 **4b**	 **6b**, R = Ts; 91 % **7b**, R = H; 90%
4	 **4c**	 **6c**, R = Ts; 100 % **7c**, R = H; 95 %
5	 **4d**	 **6d**, R^1 = TBS, R = Ts; 93 % **7d**, R^1, R = H; 83 %
6	 **4e** (α,β ; 2.4 : 1)	 **α-6e**, R^1 = TBS, R = Ts; 60 % **α-7e**, R^1,R = H; 67 %  **β-6e**, R^1 = TBS, R = Ts; 28 % **β-7e**, R^1,R = H; 0 %
7	 **4f**	 **6f**, R = Ts; 94 % **7f**, R = H; 92 %
8	 **4g**	 **6g**, R = Ts; 89 % **7g**, R = H; 86 %
9	 **4h**	 **6h**, R = Ts; 90 % **7h**, R = H; 85 %
10	 **4i**	 **6i**, R^1 = TBDPS, R = Ts; 76 % **7i**, R^1, R = H; 0 %

one-pot reaction of alkyne **4e** required prolonged heating at elevated temperature (32 h, 140 °C) to approach completion to afford the required product β-**7e**. When we attempted to extend the scope of this strategy to the synthesis of bis-indolyl-C-glycoside from bis-alkyne **4f**, surprisingly, only selective formation of the mono indolyl-C-glycoside **7f** was observed (92%), with the propargyl moiety remaining intact.

Remarkably, to the best our knowledge, this is the first report on selective formation of mono indolyl-C-glycoside from a bis-alkynyl sugar derivative. Subsequently, mannose-derived alkynes **4g** and **4h**[8a] were also found to undergo the one-pot reaction under the optimized conditions to furnish indolyl glycosides **7g** and **7h** in 86 and 85% yields, respectively.

When we attempted to extent to one-pot reaction to include the biologically important nucleoside substrate, β-thymidine-derived alkyne **4i**, however, disapointingly, an intractable complex mixture was obtained. Nevertheless, the corresponding *N*-tosyl-indolyl-C-glycoside **6i** could be obtained from **4i** in 76% yield in the absence of TBAF.

Conclusions

We have accomplished the synthesis of a variety of *N*-tosyl-2-indolyl-C-glycosides through a cascade reaction of C-alkynyl glycosides that involves a sequential Sonogashira type coupling and cyclative-hydroamination. We have also extended this strategy to develop a one-pot synthesis of 2-indolyl-C-glycosides through TBAF-mediated removal of the *N*-tosyl group. Notable features of this protocol include tolerance to sensitive functional groups, and the selective functionalization of sugar-derived bis-alkyne. Thus, the described method serves as a straightforward alternative protocol for the synthesis of 2-indolyl-*C*-glycosides, and also facilitates the synthesis of related natural products. Further efforts to extend the scope of this methodology will include the total synthesis of α-C-mannosyl-tryptophan and its analogues by taking advantage of a precedent report.[16]

Experimental Section

General Methods: Unless and otherwise noted, all starting materials and reagents were obtained from commercial suppliers and used after further purification as detailed below. *N*-Methyl-2-pyrrolidone (NMP), *N*,*N*-dimethylformamide, and triethylamine were freshly distilled from calcium hydride. All solvents for routine isolation of products and chromatography were reagent grade and glass distilled. Reaction flasks were dried in an oven at 100 °C for 12 h. Air- and moisture-sensitive reactions were performed under an argon/UHP nitrogen atmosphere. Column chromatography was performed using silica gel (100–200 mesh, Aceme) with indicated solvents. All reactions were monitored by thin-layer chromatography carried out on 0.25 mm E. Merck silica plates (60F-254) using UV light to visualize the spots, and aqueous phosphomolybdic acid containing concd. H_2SO_4 and heat as developing agents. Optical rotation was recorded with an Autopol IV automatic polarimeter. IR spectra were recorded with a Thermo Nicolet Avater 320 FTIR and a Nicolet Impact 400 machine. Mass spectra were obtained with a Waters Micromass-Q-Tof microTM (YA105) spectrometer.

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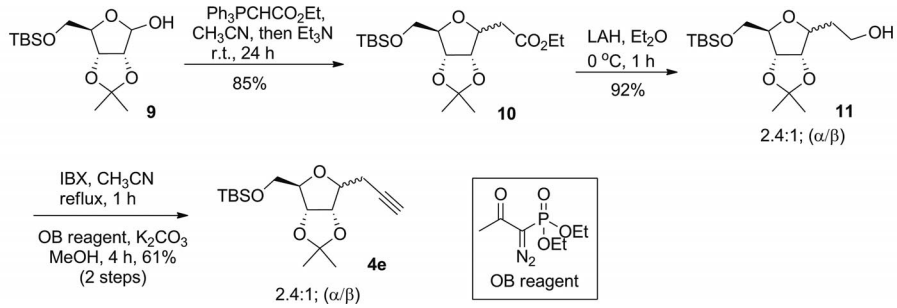


^{1}H and ^{13}C NMR spectra were recorded with a Bruker AV 400 MHz. NMR spectroscopic data is given in the order: chemical shift, multiplicity (s, singlet; br. s, broad singlet; d, doublet; t, triplet; q, quartet; m, multiplet), coupling constant in Hertz (Hz), and number of protons.

Synthesis of Ribose-Derived Alkyne 4e

Ribose Derived Ester 10: To a solution of lactol **9** (2.4 g, 8.21 mmol) in CH_3CN was added ethoxycycarbonlymethylenetriphenyl phosphorane (5.72 g, 16.43 mmol) followed by Et_3N (1.71 mL, 12.32 mmol) at room temp. and the mixture was stirred for 24 h. The reaction mixture was concentrated under reduced pressure and the resulting residue was purified by column chromatography to obtain ester **10** (2.6 g, 88%) as a pale-yellow liquid. $[\alpha]_D^{20}$ = –11.40 (c = 4.91, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.59 (dd, J = 6.5, 3.1 Hz, 1 H), 4.37 (dd, J = 6.3, 4.4 Hz, 1 H), 4.25 (dd, J = 11.1, 6.6 Hz, 1 H), 4.14–4.05 (m, 2 H), 4.00 (q, J = 6.5, 3.3 Hz, 1 H), 3.63 (d, J = 3.1 Hz, 2 H), 2.55 (d, J = 6.3 Hz, 2 H), 1.47 (s, 3 H), 1.27 (s, 3 H), 1.18 (t, J = 7.16 Hz, 3 H), 0.83 (s, 9 H), 0.00 (s, 6 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 170.7, 113.7, 84.9, 84.7, 82.1, 81.3, 63.9, 60.5, 38.9, 27.5, 60.0, 25.6, 18.4, 14.2, –5.2, –5.4 ppm. IR (neat): $\tilde{\nu}$ = 2983, 2954, 2932, 2858, 1740, 1472, 1258, 1080, 837, 778 cm^{-1}. HRMS (ESI): calcd. for $C_{18}H_{35}O_6Si$ [M + H] 375.2203; found 375.2209.

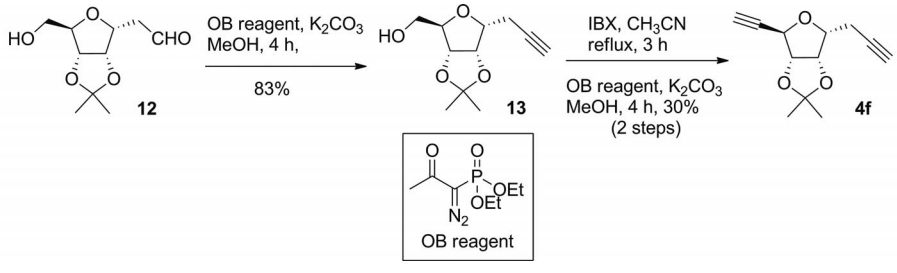
Ribose-Derived Alcohol 11:[17] To a suspension of $LiAlH_4$ (296 mg, 7.99 mmol) in diethyl ether (10 mL) at 0 °C, was added ester **10** (1.5 g, 3.99 mmol) dissolved in anhydrous diethyl ether (15 mL). The reaction mixture was stirred at the same temperature for 30 min, then quenched by slow addition of saturated Na_2SO_4 solution at 0 °C and the resulting milky emulsion was stirred up to give a clear solution at room temp. This mixture was filtered through a Celite pad and washed with ethyl acetate. The combined filtrates were dried with anhydrous Na_2SO_4, concentrated under reduced pressure, and purified by column chromatography to afford alcohol **11** as a colorless liquid (1.22 g, 92%). $[\alpha]_D^{20}$ = –10.28 (c = 1.28, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.65 (dd, J = 6.7, 3.5 Hz, 1 H), 4.37 (dd, J = 6.7, 5.3 Hz, 1 H), 4.06 (m, 2 H), 3.79 (t, J = 5.3 Hz, 2 H), 3.74 (dd, J = 3.5, 1.0 Hz, 2 H), 1.95–1.81 (m, 2 H), 1.53 (s, 3 H), 1.35 (s, 3 H), 0.89 (s, 9 H), 0.07 (s, 3 H), 0.06 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 114.3, 84.9, 84.7, 84.3, 81.6, 63.5, 60.9, 35.5, 27.6, 26.0, 25.7, 18.5, –5.1, –5.3 ppm. IR (neat): $\tilde{\nu}$ = 3504, 3019, 2931, 2858, 1256, 1216, 1074, 758, 669 cm^{-1}. HRMS (ESI): calcd. for $C_{16}H_{32}O_5NaSi$ [M + Na] 355.1917; found 355.1905.

Ribose-Derived TBS Ether Alkyne 4e: To a stirred solution of alcohol **11** (1.2 mg, 3.61 mmol) in CH_3CN (20 mL) was added 2-iodoxybenzoic acid (IBX; 2.51 g, 9.03 mmol) at room temp. and the resulting suspension was heated to reflux for 5 h. The reaction mixture was filtered through a Celite pad and washed with ethyl acetate (10 mL). The combined filtrates were dried with anhydrous Na_2SO_4 and concentrated under reduced pressure to give the aldehyde (1.0 g), which was used in the next step without further purification.

To a suspension of anhydrous K_2CO_3 (840 mg, 6.06 mmol) in anhydrous MeOH (20 mL) under nitrogen, was added dimethyl (1-diazo-2-oxopropyl)phosphonate (1.04 mL, 6.06 mmol) at room temp. The mixture was stirred at room temp. for 30 min, then the above aldehyde dissolved in MeOH (20 mL) was added and the mixture was stirred for 5 h. The reaction mixture was filtered through a Celite pad and washed with MeOH (10 mL). The combined filtrates were dried with anhydrous Na_2SO_4, concentrated under reduced pressure, and purified by column chromatography to give alkyne **4e** (710 mg, 61%; α,β 2.4:1) as an oil. $[\alpha]_D^{20}$ = –15.80 (c = 0.82, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 4.75 (d, J = 6.1 Hz, 1 H), 4.65 (t, J = 4.3 Hz, 1 H), 4.19 (q, J = 11.0, 7.0 Hz, 1 H), 4.02 (t, J = 3.6 Hz, 1 H), 3.67–3.63 (m, 2 H), 2.47 (dd, J = 7.0, 2.4 Hz, 2 H), 1.95–1.94 (m, 1 H), 1.42 (s, 3 H), 1.29 (s, 3 H), 0.83 (s, 9 H), 0.00 (s, 6 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 112.5, 84.6, 83.2, 82.1, 81.7, 81.1, 69.4, 65.0, 26.4, 25.9, 25.1, 19.7, 18.2, –5.4, –5.3 ppm. IR (neat): $\tilde{\nu}$ = 3313, 2953, 2931, 2858, 1643, 1382, 1257, 1097, 1077, 838, 777, 638 cm^{-1}. HRMS (ESI): calcd. for $C_{17}H_{31}O_4Si$ [M + H] 327.1992; found 327.2007.

Synthesis of Ribose-Derived Alkyne 4f

Ribose-Derived Alkyne 13: To a solution of dimethyl (1-diazo-2-oxopropyl)phosphonate (0.86 mL, 4.97 mmol) in MeOH (15 mL) under nitrogen was added anhydrous K_2CO_3 (690 mg, 4.97 mmol) at room temp. The mixture was stirred at room temp. for 30 min,



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then aldehyde **12**[18] (530 mg, 1.99 mmol) dissolved in MeOH (10 mL) was added and the mixture was stirred for 5 h. The reaction mixture was filtered through a Celite pad and washed with MeOH (10 mL). The combined filtrates were dried with anhydrous Na_2SO_4, concentrated under reduced pressure, and purified by column chromatography to give alkyne **13** (350 mg, 83%) as an oil. $[\alpha]_D^{20}$ = –11.16 (*c* = 1.20, $CHCl_3$). ^1H NMR (400 MHz, $CDCl_3$): δ = 4.74 (dd, *J* = 6.1, 3.9 Hz, 1 H), 4.67 (dd, *J* = 6.1, 1.3 Hz, 1 H), 4.18–4.07 (m, 2 H), 3.69–3.61 (m, 2 H), 2.61 (dd, *J* = 2.6, 1.6 Hz, 1 H), 2.59 (dd, *J* = 2.6, 1.3 Hz, 1 H), 2.03 (t, *J* = 2.6 Hz, 1 H), 1.50 (s, 3 H), 1.35 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 113.1, 84.6, 82.5, 81.2, 80.9, 79.7, 69.7, 62.3, 26.4, 25.2, 19.5 ppm. IR (neat): $\tilde{\nu}$ = 3460, 3303, 2983, 2933, 1739, 1382, 1212, 1163, 1105, 1037, 869, 759, 667 cm^{-1}. HRMS (ESI): calcd. for $C_{11}H_{16}O_4Na$ [M + Na] 235.0946; found 235.0950.

Ribose-Derived Bis-alkyne 4f: To a stirred solution of alcohol **13** (320 mg, 1.50 mmol) in CH_3CN (15 mL) was added 2-iodoxybenzoic acid (IBX; 1.04 g, 3.77 mmol) at room temp. and the resulting suspension was heated to reflux for 3 h. The reaction mixture was filtered through a Celite pad and washed with ethyl acetate (10 mL). The combined filtrates were dried with anhydrous Na_2SO_4 and concentrated to give the aldehyde (300 mg), which was used in the next step without further purification.

To a suspension of anhydrous K_2CO_3 (500 mg, 3.56 mmol) in anhydrous MeOH (10 mL) under nitrogen, was added dimethyl (1-diazo-2-oxopropyl)phosphonate (0.61 mL, 3.56 mmol) at room temp. The mixture was stirred at room temp. for 30 min, then the above aldehyde dissolved in MeOH (10 mL) was added and the mixture was stirred for 5 h. The reaction mixture was filtered through a Celite pad and washed with MeOH (10 mL). The combined filtrates were dried with anhydrous Na_2SO_4, concentrated under reduced pressure and purified by column chromatography to give alkyne **4f** (92 mg, 30%) as an oil. $[\alpha]_D^{20}$ = –33.04 (*c* = 1.26, $CHCl_3$). ^1H NMR (400 MHz, $CDCl_3$): δ = 4.82 (d, *J* = 5.9 Hz, 1 H), 4.77 (dd, *J* = 5.9, 3.4 Hz, 1 H), 4.71 (d, *J* = 2.2 Hz, 1 H), 4.14 (td, *J* = 7.3, 3.4 Hz, 1 H), 2.64 (dt, *J* = 7.3, 2.9 Hz, 2 H), 2.49 (d, *J* = 2.2 Hz, 1 H), 2.04 (t, *J* = 2.9 Hz, 1 H), 1.47 (s, 3 H), 1.34 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 113.2, 86.4, 80.4, 80.3, 79.6, 79.3, 75.7, 73.7, 69.8, 26.1, 25.2, 18.4 ppm. IR (neat): $\tilde{\nu}$ = 3295, 2988, 2939, 1658, 1378, 1216, 1163, 1088, 869, 759, 649 cm^{-1}. HRMS (ESI): calcd. for $C_{12}H_{14}O_3Na$ [M + Na] 229.0841; found 229.0848.

Synthesis of Thymidine-Derived Alkyne 4i

Thymidine-Derived Alkyne 4i: To a stirred solution of alcohol **14**[19] (1.37 g, 2.85 mmol) in CH_3CN (50 mL) was added 2-iodoxybenzoic acid (IBX; 2 g, 7.13 mmol) at room temp. and the resulting suspension was heated to reflux for 2.5 h. The reaction mixture was filtered through a Celite pad and washed with ethyl acetate (30 mL). The combined filtrates were dried with anhydrous Na_2SO_4 and concentrated to give the aldehyde (1.27 mg), which was used in the next step without further purification.

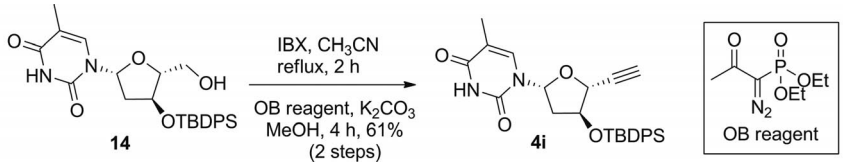
To a suspension of anhydrous K_2CO_3 (916 mg, 6.63 mmol) in anhydrous MeOH (20 mL) under nitrogen, was added dimethyl (1-diazo-2-oxopropyl)phosphonate (1.14 mL, 6.63 mmol) at room temp. The mixture was stirred at room temp. for 30 min, then the above aldehyde dissolved in MeOH (20 mL) was added and the mixture was stirred for 5 h. The reaction mixture was filtered through a Celite pad and washed with MeOH (15 mL). The combined filtrates were dried with anhydrous Na_2SO_4, concentrated under reduced pressure, and purified by column chromatography to give alkyne **4i** (760 mg, 61%) as a viscous oil. $[\alpha]_D^{20}$ = 77.25 (*c* = 0.35, $CHCl_3$). ^1H NMR (400 MHz, $CDCl_3$): δ = 9.84 (br. s, 1 H), 7.66–7.48 (m, 4 H), 7.48–7.34 (m, 6 H), 6.56 (dd, *J* = 8.4, 5.8 Hz, 1 H), 4.62 (t, *J* = 1.0 Hz, 1 H), 4.51 (d, *J* = 4.2 Hz, 1 H), 2.61 (d, *J* = 2.2 Hz, 1 H), 2.47 (dd, *J* = 13.7, 5.8 Hz, 1 H), 2.05–1.94 (m, 1 H), 1.88 (d, *J* = 1.0 Hz, 3 H), 1.10 (s, 9 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 164.3, 150.6, 135.7, 135.7, 132.7, 132.5, 130.2, 130.2, 128.0, 128.0, 111.2, 86.9, 80.3, 78.6, 77.5, 77.2, 40.3, 26.8, 19.0, 12.8 ppm. IR (neat): $\tilde{\nu}$ = 3299, 3018, 2932, 2859, 1694, 1471, 1112, 758, 702, 508 cm^{-1}. HRMS (ESI): calcd. for $C_{27}H_{31}N_2O_4Si$ [M + H] 475.2053; found 475.2049.

General Procedures for 2-Indolyl-*C*-glycosides

Procedure A: $[Pd(PPh_3)_2Cl_2]$ (3 mg, 3 mol-%), 2-iodoaniline (30 mg, 0.75 mmol), CuI (2 mg, 6 mol-%), triethylamine (0.025 mL, 0.182 mmol), galactose derived alkyne **4** (28 mg, 0.109 mmol), and DMF (5 mL) were heated to reflux for 24 h under an N_2 atmosphere. The reaction mixture was diluted with saturated aqueous ammonium chloride and the product was extracted with ethyl acetate. The organic layer was dried with Na_2SO_4 and filtered. The crude product was purified by silica gel column chromatography to afford diastereomeric product **8** (27 mg, *dr* 3:1, 87%) as a brown syrup. R_f = 0.40 (20% ethyl acetate in hexanes). $[\alpha]_D^{20}$ = +3.38 (*c* = 0.78, $CHCl_3$). ^1H NMR (400 MHz, $CDCl_3$): δ = 7.27 (dd, *J* = 7.5, 1.5 Hz, 1 H), 7.15 (dt, *J* = 7.5, 1.5 Hz, 1 H), 6.65 (dd, *J* = 7.68, 0.64 Hz, 1 H), 6.63 (dt, *J* = 7.68, 0.64 Hz, 1 H), 5.60 (d, *J* = 5.1 Hz, 1 H), 4.81 (d, *J* = 2.2 Hz, 1 H), 4.67 (dd, *J* = 7.68, 2.6 Hz 1 H), 4.47 (br. s, 2 H), 4.38–4.35 (m, 2 H), 1.58 (s, 3 H), 1.53 (s, 3 H), 1.39 (s, 3 H), 1.35 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 149.4, 132.1, 130.2, 117.5, 114.1, 109.9, 109.1, 106.93, 96.6, 89.8, 83.8, 73.2, 71.03, 70.2, 61.1, 26.3, 26.2, 25.0, 24.9 ppm. IR (neat): $\tilde{\nu}$ = 3479, 3369, 2927, 2855, 2232, 1619, 1216, 1070, 901, 767, 669 cm^{-1}. HRMS (ESI): calcd. for $C_{19}H_{24}NO_5$ [M + H] 346.1654; found 346.1650.

Procedure B: $[Pd(OAc)_2]$ (2 mg, 5 mol-%), nBu$_4$NBr (63 mg, 0.196 mmol), Na_2CO_3 (104 mg, 0.984 mmol), *N*-tosyl-*o*-iodoaniline **5** (146 mg, 0.236 mmol), galactose-derived alkyne **4** (50 mg, 0.196 mmol), and PPh_3 (2 mg, 5 mol-%) were taken in DMF (10 mL) and heated at 100 °C for 30 h under an N_2 atmosphere. The reaction mixture was diluted with diethyl ether and washed with saturated aqueous NH_4Cl and H_2O. The organic layer was dried with Na_2SO_4, the reaction mixture was filtered and concentrated, and the product was purified by column chromatography to provide *N*-tosyl-indolyl-C-galactoside **6** (18 mg, 18%).

Procedure C: $[Pd(OAc)_2]$ (7 mg, 30 mol-%), *N*-tosyl-*o*-iodoaniline **5** (146 mg, 0.236 mmol), galactose-derived alkyne **4** (50 mg, 0.196 mmol), and triethylamine (0.05 mL, 0.393 mmol) were taken in NMP (3 mL) and the reaction was heated under microwave con-



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ditions (100 W, 125 °C) [CEM focused microwave oven, model Discoverer] for 50 min. The reaction mixture was diluted with diethyl ether and washed with saturated aqueous NH_4Cl and H_2O. The organic layer was dried with Na_2SO_4 and the crude product was purified by column chromatography to provide *N*-tosyl-2-indolyl-C-galactoside **6** (54 mg, 55%).

Procedure D: To a suspension of $[Cu(phen)(PPh_3)_2]NO_3$ (8 mg, 10 mol-%), 2-iodoaniline (20 mg, 0.091 mmol), galactose derived alkyne **4** (28 mg, 0.109 mmol) in toluene (5.0 mL), was added Cs_2CO_3 (60 mg, 0.182 mmol) under an N_2 atmosphere, and the reaction was stirred at 110 °C for 24 h. When the reaction was complete, *t*BuONa (18 mg, 0.183 mmol) was added under an N_2 atmosphere, and the reaction mixture was further stirred at 110 °C for 2 h. Sat. NH_4Cl solution (25 mL) was added, the mixture was extracted with CH_2Cl_2, and the combined organic phase was dried with anhydrous Na_2SO_4, filtered, and the solvent was removed. The solid residue was purified by column chromatography to afford Sonogashira type diastereomeric product **8** as a syrup (67%, *dr* 1.75:1).

Procedure E: To a solution of sugar-derived alkyne (0.096 mmol, 1.2 equiv.) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol, 1 equiv.) in toluene (4 mL) was added $[Cu(Phen)(PPh_3)_2]NO_3$catalyst (7 mg, 10 mol-%), then anhydrous K_3PO_4 (51 mg, 0.241 mmol, 3 equiv.) under an N_2 atmosphere, and the reaction mixture was heated at 110 °C for 9–11 h. When the starting material was consumed, the reaction was diluted with ethyl acetate and washed with water, the aqueous layer was washed with ethyl acetate and the combined organic layers were dried with anhydrous Na_2SO_4 and concentrated.

General One-pot Reaction Procedure F: To a solution of sugar-derived alkyne (0.096 mmol, 1.2 equiv.), and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol) in toluene (4 mL), was added $[Cu(Phen)(PPh_3)_2]NO_3$ (7 mg, 10 mol-%) catalyst, then anhydrous K_3PO_4 (51 mg, 0.241 mmol, 3 equiv.) under an N_2 atmosphere. The reaction mixture was heated at 110 °C for 9–11 h. When the starting material *N*-tosyl-*o*-iodoaniline **6** was consumed (reaction monitored by TLC), the reaction mixture was brought to room temp., TBAF (1 M in THF, 5–7 equiv.) was added and the mixture was further heated at 110 °C for 2–3 h. The reaction was then diluted with ethyl acetate and washed with water. The aqueous layer was extracted with ethyl acetate, and the combined organic layers were dried with anhydrous Na_2SO_4 and then concentrated.

Synthesis of *N*-Tosyl-2-indolyl-C-glycosides

***N*-Tosyl-2-indolyl-C-galactoside 6:** Following General Procedure E, the reaction was carried out between galactose-derived alkyne **4** (25 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **6** (33 mg, 82%) as a pale-yellow solid. R_f = 0.40 (20% ethyl acetate in hexanes); m.p. 66–70 °C; $[\alpha]_D^{20}$ = +3.38 (*c* = 0.78, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.02 (d, *J* = 8.1 Hz, 1 H), 7.58 (d, *J* = 8.4 Hz, 2 H), 7.43 (dd, *J* = 7.0, 1.7 Hz, 1 H), 7.23–7.17 (m, 2 H), 7.14 (d, *J* = 8.4 Hz, 2 H), 6.85 (s, 1 H), 5.83 (s, 1 H), 5.73 (d, *J* = 5.2 Hz, 1 H), 4.74 (d, *J* = 1.9 Hz, 1 H), 4.74 (s, 1 H), 4.44 (dd, *J* = 1.9, 5.2 Hz, 1 H), 2.29 (s, 3 H), 1.64 (s, 3 H), 1.45 (s, 3 H), 1.39 (s, 3 H), 1.29 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.8, 137.5, 137.3, 135.2, 130.4, 129.8, 126.5, 124.4, 123.9, 121.1, 115.3, 113.0, 109.4, 109.0, 97.4, 72.8, 71.5, 70.9, 65.1, 26.2, 26.1, 25.1, 24.5, 21.6 ppm. IR (neat): $\tilde{\nu}$ = 3356, 3258, 2924, 2853, 1597, 1452, 1372, 1299, 1090, 901, 580, 534 cm^{-1}. HRMS (ESI): calcd. for $C_{26}H_{30}NO_7S$ [M + H] 500.1743; found 500.1755.

***N*-Tosyl-2-indolyl-C-glucoside 6a:** Following General Procedure E, the reaction was carried out between glucose-derived alkyne **4a** (26 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30, 0.08 mmol). Column chromatography on silica gel gave the title compound **6a** (41 mg, 98%) as a colorless liquid. R_f = 0.30 (10% ethyl acetate in hexanes); $[\alpha]_D^{20}$ = +109.43 (*c* = 1.79, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.17 (d, *J* = 8.4 Hz, 1 H), 7.59 (d, *J* = 8.4 Hz, 2 H), 7.48 (d, *J* = 7.32 Hz, 1 H), 7.31 (td, *J* = 8.4, 1.3 Hz, 1 H), 7.24 (td, *J* = 7.3, 1.1 Hz, 1 H), 7.20–7.12 (m, 5 H), 6.97 (d, *J* = 8.4 Hz, 2 H), 6.95 (s, 1 H), 6.06 (d, *J* = 3.7 Hz, 1 H), 5.82 (d, *J* = 2.1 Hz, 1 H), 4.69 (d, *J* = 3.7 Hz, 1 H), 4.53 (d, *J* = 2.1 Hz, 1 H), 4.35 (d, *J* = 11.7 Hz, 1 H), 4.19 (d, *J* = 11.7 Hz, 1 H), 2.30 (s, 3 H), 1.59 (s, 3 H), 1.37 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 145.1, 137.40, 137.3, 135.7, 135.4, 130.0, 128.6, 128.4, 127.8, 127.8, 126.4, 124.6, 123.9, 121.1, 114.8, 112.4, 112.1, 104.6, 84.0, 83.1, 77.6, 72.8, 27.3, 26.6, 21.7 ppm. IR (neat): $\tilde{\nu}$ = 3020, 2932, 1597, 1452, 1374, 1218, 1091, 1025, 758, 580, 548 cm^{-1}. HRMS (ESI): calcd. for [M + H] $C_{29}H_{30}NO_6S$ 520.1794; found 520.1791.

***N*-Tosyl-2-indolyl-C-glucoside 6b:** Following the General Procedure E, the reaction was carried out between glucose-derived alkyne **4b** (18 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **6b** (31 mg, 91%) as a white solid. R_f = 0.25 (20% ethyl acetate in hexanes); m.p. 122–126 °C; $[\alpha]_D^{20}$ = +77.96 (*c* = 1.81, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.14 (d, *J* = 8.2 Hz, 1 H), 7.63 (d, *J* = 8.4 Hz, 2 H), 7.48 (d, *J* = 7.5 Hz, 1 H), 7.31 (td, *J* = 7.5, 1.3 Hz, 1 H), 7.23 (td, *J* = 8.2, 0.9 Hz, 1 H), 7.18 (d, *J* = 8.4 Hz, 2 H), 6.93 (s, 1 H), 6.05 (d, *J* = 3.6 Hz, 1 H), 5.88 (d, *J* = 1.4 Hz, 1 H), 4.67 (d, *J* = 3.6 Hz, 2 H), 2.32 (s, 3 H), 1.61 (s, 3 H), 1.38 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 145.3, 137.5, 135.4, 134.4, 130.1, 129.4, 126.4, 125.0, 124.0, 121.1, 114.7, 112.6, 112.2, 104.5, 85.2, 78.2, 75.8, 27.2, 26.5, 21.7 ppm. IR (neat): $\tilde{\nu}$ = 3020, 2932, 1597, 1452, 1374, 1218, 1091, 1025, 758, 580, 548 cm^{-1}. HRMS (ESI): calcd. for [M + H] $C_{22}H_{24}NO_6S$ 430.1324; found 430.1335.

***N*-Tosyl-2-indolyl-C-riboside 6c:** Following General Procedure E, the reaction was carried out between ribose-derived alkyne **4c** (19 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **6c** (35.4 mg, 100%) as a white solid. R_f = 0.42 (15% ethyl acetate in hexanes); m.p. 138–142 °C; $[\alpha]_D^{20}$ = –49.34 (*c* = 1.30, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.01 (d, *J* = 8.2 Hz, 1 H), 7.70 (d, *J* = 8.4 Hz, 2 H), 7.47 (d, *J* = 8.2 Hz, 1 H), 7.26–7.19 (m, 2 H), 7.17 (d, *J* = 8.4 Hz, 2 H), 6.88 (s, 1 H), 5.68 (d, *J* = 3.7 Hz, 1 H), 5.18 (dd, *J* = 5.8, 3.7 Hz, 1 H), 5.05 (s, 1 H), 4.69 (d, *J* = 5.8 Hz, 1 H), 3.37 (s, 3 H), 2.31 (s, 3 H), 1.37 (s, 3 H), 1.28 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.8, 136.8, 135.8, 135.8, 129.7, 129.7, 126.6, 124.3, 123.5, 120.9, 114.5, 112.7, 111.7, 106.3, 85.1, 80.6, 76.7, 54.8, 26.0, 24.9, 21.5 ppm. IR (neat): $\tilde{\nu}$ = 2983, 2935, 2835, 1597, 1453, 1372, 1174, 1092, 1029, 751, 575, 545 cm^{-1}. HRMS (ESI): calcd. for $C_{23}H_{25}NO_6S$ [M + H] 444.1481; found 444.1492.

***N*-Tosyl-2-indolyl-*C*-riboside 6d:** Following the General Procedure E, the reaction was carried out between ribose-derived alkyne **4d** (30 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **6d** (41 mg, 93%) as a syrup. R_f = 0.40 (10% ethyl acetate in hexanes); $[\alpha]_D^{20}$ = +3.59 (*c* = 1.69, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.95 (d, *J* = 8.0 Hz, 1 H), 7.70 (d, *J* = 8.4 Hz, 2 H), 7.45 (dd, *J* = 6.9, 2.2 Hz, 1 H), 7.21 (dd, *J* = 8.0, 1.6 Hz, 1 H), 7.18 (dd, *J* = 6.9, 1.6 Hz, 1 H), 7.14 (d, *J* = 8.4 Hz, 2 H), 6.87 (d, *J* = 0.8 Hz, 1 H), 5.88 (dd, *J* = 4.5, 0.8 Hz, 1 H), 5.26 (dd, *J* = 5.9, 4.9 Hz, 1 H), 4.92 (d, *J* = 5.9 Hz, 1 H), 4.33 (t, *J* = 3.1 Hz, 1 H), 3.87 (dd, *J* = 3.1, *J* = 11.0 Hz, 1 H), 3.81 (dd, *J*

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= 3.1, 11.0 Hz, 1 H), 2.31 (s, 3 H), 1.29 (s, 3 H), 1.28 (s, 3 H), 0.94 (s, 9 H), 0.11 (s, 6 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.7, 138.4, 136.9, 136.1, 129.9, 129.8, 126.8, 124.1, 123.4, 120.9, 114.5, 112.5, 110.7, 84.0, 83.6, 83.0, 80.5, 65.5, 26.2, 26.1, 25.2, 21.6, 18.4, –5.2, –5.3 ppm. IR (neat): $\tilde{\nu}$ = 2931, 2857, 1597, 1453, 1371, 1174, 1091, 838, 747, 580 cm^{-1}. HRMS (ESI): calcd. for $C_{29}H_{40}NO_6SSi$ [M + H] 558.2346; found 558.2347.

***N*-Tosyl-2-indolyl-C-ribosides α-6e and β-6e:** Following the General Procedure E, the reaction was carried out between ribose-derived alkyne **4e** (31 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compounds, α-**6e** (31 mg, 68%; R_f = 0.50, 10% ethyl acetate in hexanes) and β-**6e** (12 mg, 26%; R_f = 0.52, 10% ethyl acetate in hexanes) as syrups.

α-6e: $[\alpha]_D^{20}$ = –45.57 (*c* = 0.89, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.14 (d, *J* = 8.3 Hz, 1 H), 7.63 (d, *J* = 8.4 Hz, 2 H), 7.39 (d, *J* = 7.8 Hz, 1 H), 7.26–7.14 (m, 4 H), 6.54 (s, 1 H), 4.83 (d, *J* = 6.1 Hz, 1 H), 4.77 (dd, *J* = 6.1, 3.9 Hz, 1 H), 4.59 (quint, *J* = 3.9 Hz, 1 H), 4.10 (t, *J* = 3.8 Hz, 1 H), 3.68 (dd, *J* = 3.9, 2.05 Hz, 2 H), 3.49 (dd, *J* = 16.1, 3.8 Hz, 1 H), 3.24 (dd, *J* = 16.1, 7.9 Hz, 1 H), 2.31 (s, 3 H), 1.54 (s, 3 H), 1.38 (s, 3 H), 0.87 (s, 9 H), 0.04 (s, 3 H), 0.02 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.7, 138.9, 137.3, 136.1, 130.1, 129.9, 126.5, 124.0, 123.6, 120.5, 115.0, 112.3, 110.8, 84.5, 83.3, 82.3, 81.1, 64.7, 30.1, 26.5, 26.0, 25.3, 21.7, 18.3, –5.3, –5.4 ppm. IR (neat): $\tilde{\nu}$ = 2930, 2857, 1597, 1453, 1371, 1175, 1091, 838, 584, 544 cm^{-1}. HRMS (ESI): calcd. for $C_{30}H_{41}NO_6SSiNa$ [M + Na] 594.2322; found 594.2318.

β-6e: $[\alpha]_D^{20}$ = –1.79 (*c* = 1.81, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.14 (d, *J* = 7.6 Hz, 1 H), 7.61 (d, *J* = 8.4 Hz, 2 H), 7.42 (d, *J* = 7.3 Hz, 1 H), 7.27–7.21 (m, 2 H), 7.16 (d, *J* = 8.4 Hz, 2 H), 6.58 (d, *J* = 0.6 Hz, 1 H), 4.68 (dd, *J* = 6.5, 3.4 Hz, 1 H), 4.45 (dd, *J* = 6.5, 4.4 Hz, 1 H), 4.40–4.35 (m, 1 H), 4.08 (dd, *J* = 7.2, 4.4 Hz, 1 H), 3.73 (d, *J* = 3.4 Hz, 2 H), 3.37 (dd, *J* = 16.8, 6.0 Hz, 1 H), 3.27 (dd, *J* = 16.8, 6.0 Hz, 1 H), 2.32 (s, 3 H), 1.55 (s, 3 H), 1.34 (s, 3 H), 0.91 (s, 9 H), 0.08 (s, 3 H), 0.07 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.8, 138.0, 137.2, 136.3, 130.0, 127.9, 126.4, 124.2, 123.6, 120.6, 114.9, 114.0, 110.5, 85.2, 84.9, 83.4, 82.1, 63.9, 33.8, 27.6, 26.1, 25.7, 21.7, 18.5, –5.0, –5.2 ppm. IR (neat): $\tilde{\nu}$ = 3019, 2930, 2851, 1452, 1372, 1216, 1092, 759, 669 cm^{-1}. HRMS (ESI): calcd. for $C_{30}H_{41}NO_6SSiNa$ [M + Na] 594.2322; found 594.2313.

***N*-Tosyl-2-indolyl-C-riboside 6f:** Following General Procedure E, the reaction was carried out between ribose-derived alkyne **4f** (20 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **6f** (34 mg, 94%) as a syrup. R_f = 0.40 (10% ethyl acetate in hexanes); $[\alpha]_D^{20}$ = +190.23 (*c* = 0.81, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.12 (d, *J* = 8.2 Hz, 1 H), 7.81 (d, *J* = 8.4 Hz, 2 H), 7.44 (d, *J* = 7.5 Hz, 1 H), 7.30 (td, *J* = 8.2, 1.3 Hz, 1 H), 7.23 (td, *J* = 7.5, 1.0 Hz, 1 H), 7.14 (d, *J* = 8.4 Hz, 2 H), 6.61 (s, 1 H), 5.78 (s, 1 H), 5.24 (d, *J* = 6.0 Hz, 1 H), 4.71 (dd, *J* = 6.0, 3.8 Hz, 1 H), 4.23 (td, *J* = 6.9, 3.8 Hz, 1 H), 2.71–2.67 (m, 2 H), 2.30 (s, 3 H), 2.06 (t, *J* = 8.0 Hz, 1 H), 1.41 (s, 3 H), 1.25 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 145.2, 137.6, 137.6, 135.0, 129.8, 129.4, 126.9, 125.2, 124.2, 121.1, 115.2, 112.9, 111.2, 86.9, 81.8, 80.9, 80.6, 79.8, 69.7, 26.4, 25.2, 21.7, 19.1 ppm. IR (neat): $\tilde{\nu}$ = 3294, 2924, 2851, 1740, 1711, 1452, 1373, 1175, 1090, 752, 579 cm^{-1}. HRMS (ESI): calcd. for $C_{25}H_{26}NO_5S$ [M + H] 452.1532; found 452.1528.

***N*-Tosyl-2-indolyl-*C*-mannoside 6g:** Following General Procedure E, the reaction was carried out between mannose-derived alkyne **4g** (19 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **6g** (32 mg, 89%) as a white solid. R_f = 0.42 (15% ethyl acetate in hexanes); m.p. 168–172 °C; $[\alpha]_D^{20}$ = 149.76 (*c* = 1.50, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.01 (dd, *J* = 8.1, 0.7 Hz, 1 H), 7.71 (d, *J* = 8.4 Hz, 2 H), 7.47 (dd, *J* = 7.2, 1.7 Hz, 1 H), 7.23 (dd, *J* = 8.1, 1.4 Hz, 1 H), 7.20 (dd, *J* = 7.2, 1.3 Hz, 1 H), 7.17 (d, *J* = 8.4 Hz, 2 H), 6.88 (t, *J* = 0.9 Hz, 1 H), 5.68 (d, *J* = 3.8 Hz, 1 H), 5.18 (dd, *J* = 5.8, 3.8 Hz, 1 H), 5.05 (s, 1 H), 4.69 (d, *J* = 5.80 Hz, 1 H), 3.37 (s, 3 H), 2.32 (s, 3 H), 1.37 (s, 3 H), 1.28 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.8, 136.8, 135.8, 135.8, 129.7, 129.7, 126.6, 124.3, 123.5, 120.9, 114.5, 112.7, 111.7, 106.3, 85.1, 80.6, 76.7, 54.8, 26.0, 24.9, 21.5 ppm. IR (neat): $\tilde{\nu}$ = 2983, 2933, 2851, 1597, 1453, 1213, 1174, 1092, 1029, 749, 575, 545 cm^{-1}. HRMS (ESI): calcd. for $C_{23}H_{25}NO_6SNa$ [M + Na] 466.1300; found 466.1297.

***N*-Tosyl-2-indolyl-C-glycoside 6h:** Following the General Procedure E, the reaction was carried out between mannose-derived alkyne **4h** (16 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **6h** (30 mg, 90%) as a syrup. R_f = 0.35 (10% ethyl acetate in hexanes); $[\alpha]_D^{20}$ = 20.39 (*c* = 0.71, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.99 (d, *J* = 8.2 Hz, 1 H), 7.68 (d, *J* = 8.9 Hz, 2 H), 7.47 (d, *J* = 7.1 Hz, 1 H), 7.26–7.19 (m, 2 H), 7.16 (d, *J* = 8.9 Hz, 2 H), 6.89 (s, 1 H), 5.22 (d, *J* = 3.5 Hz, 1 H), 5.17 (dd, *J* = 5.9, 3.5 Hz, 1 H), 4.91 (dd, *J* = 5.9, 3.6 Hz, 1 H), 4.19 (d, *J* = 10.6 Hz, 1 H), 3.69 (dd, *J* = 10.6, 3.60 Hz 1 H), 2.31 (s, 3 H), 1.38 (s, 3 H), 1.29 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 144.9, 137.0, 136.1, 135.8, 129.9, 126.7, 124.4, 123.7, 121.1, 114.7, 112.5, 111.8, 99.9, 81.6, 81.5, 79.6, 72.5, 26.1, 25.0, 21.7 ppm. IR (neat): $\tilde{\nu}$ = 2930, 1673, 1454, 1370, 1216, 759, 580 cm^{-1}. HRMS (ESI): calcd. for $C_{22}H_{24}NO_5S$ [M + H] 414.1375; found 414.1364.

Thymidine-Derived *N*-Tosyl-2-indolyl-*C*-glycoside 6i: Following General Procedure E, the reaction was carried out between thymidine-derived alkyne **4i** (46 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **6i** (44 mg, 76%) as a white solid. R_f = 0.20 (50% ethyl acetate in hexanes); m.p. 109–113 °C; $[\alpha]_D^{20}$ = 77.25 (*c* = 0.35, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.15 (d, *J* = 8.4 Hz, 1 H), 8.11 (s, 1 H), 7.77 (d, *J* = 6.9 Hz, 2 H), 7.61 (dd, *J* = 7.9, 1.2 Hz, 2 H), 7.54 (d, *J* = 7.1 Hz, 2 H), 7.43–7.31 (m, 6 H), 7.26–7.21 (m, 4 H), 7.07 (d, *J* = 6.9 Hz, 2 H), 6.53 (t, *J* = 7.2 Hz, 1 H), 6.27 (br. s, 1 H), 5.65 (br. s, 1 H), 4.88 (t, *J* = 3.1 Hz, 1 H), 2.47 (ddd, *J* = 13.8, 7.2, 3.1 Hz, 1 H), 2.27 (s, 3 H), 2.17–2.04 (m, 1 H), 1.59 (s, 3 H), 1.08 (s, 9 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 163.2, 150.2, 145.2, 137.4, 135.9, 135.7, 132.7, 130.2, 130.1, 129.5, 128.3, 128.0, 127.9, 127.2, 125.8, 123.9, 121.3, 115.2, 110.9, 85.4, 82.0, 75.7, 40.6, 27.0, 21.6, 19.2, 12.3, 0.17 ppm. IR (neat): $\tilde{\nu}$ = 3020, 2929, 2860, 2110, 1693, 1216, 1113, 669 cm^{-1}. HRMS (ESI): calcd. for $C_{40}H_{42}N_3O_6SSi$ [M + H] 720.2564; found 720.2560.

Synthesis of 2-Indolyl-C-glycosides

2-Indolyl-C-galactoside 7: Following General Procedure F, the reaction was carried out between galactose-derived alkyne **4** (25 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **7** (24.7 mg, 89%) as a white solid. R_f = 0.30 (20% ethyl acetate in hexanes); m.p. 135–140 °C; $[\alpha]_D^{20}$ = –160.97 (*c* = 1.15, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$),: δ = 8.75 (br. s, 1 H), 7.57 (dd, *J* = 8.7, 0.8 Hz, 1 H), 7.37 (dd, *J* = 8.1, 0.9 Hz, 1 H), 7.15 (td, *J* = 8.7, 0.9 Hz, 1 H), 7.06 (td, *J* = 8.1, 0.8 Hz, 1 H), 6.47 (d, *J* = 2.0 Hz, 1 H), 5.65 (d, *J* = 5.0 Hz, 1 H), 5.09 (d, *J* = 1.5 Hz, 1 H), 4.71 (dd, *J* = 7.9, 2.2 Hz, 1 H), 4.50 (dd, *J* = 7.9, 1.5 Hz, 1 H), 4.38 (dd, *J* = 4.96, 2.2 Hz, 1 H), 1.62 (s, 3 H), 1.58 (s, 3 H), 1.38 (s, 3 H), 1.36

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(s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$),: δ = 136.2, 134.6, 127.7, 122.1, 120.8, 119.7, 111.3, 109.6, 108.9, 101.7, 96.8, 73.7, 71.0, 70.9, 64.4, 26.4, 26.2, 25.1, 24.1 ppm. IR (neat): $\tilde{\nu}$ = 3454, 2989, 2930, 1457, 1383, 1214, 1068,755 cm^{-1}. HRMS (ESI): calcd. for $C_{19}H_{24}NO_5$ [M + H] 346.1654; found 346.1651.

2-Indolyl-C-glucoside 7a: Following General Procedure F, the reaction was carried out between glucose-derived alkyne **4a** (26 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **7a** (23.5 mg, 81%) as a syrup. R_f = 0.35 (10% ethyl acetate in hexanes). $[\alpha]_D^{20}$ = –21.70 (c = 1.95, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.74 (br. s, 1 H), 7.61 (d, J = 7.8 Hz, 1 H), 7.29 (dd, J = 8.0, 0.7 Hz, 1 H), 7.26–7.22 (m, 2 H), 7.18 (td, J = 7.8, 0.7 Hz, 1 H), 7.10 (td, J = 8.0, 0.9 Hz, 1 H), 7.04–7.02 (m, 2 H), 6.53 (d, J = 1.4 Hz, 1 H), 6.06 (d, J = 3.8 Hz, 1 H), 5.40 (d, J = 2.9 Hz, 1 H), 4.74 (d, J = 3.8 Hz, 1 H), 4.41 (d, J = 11.4 Hz, 1 H), 4.18 (d, J = 11.4 Hz, 1 H), 4.07 (d, J = 2.9 Hz, 1 H), 1.58 (s, 3 H), 1.37 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.0, 136.5, 132.3, 128.6, 128.2, 128.1, 127.7, 122.2, 120.8, 119.7, 112.0, 111.1, 104.7, 102.4, 84.3, 83.1, 76.3, 72.9, 26.9, 26.3 ppm. IR (neat): $\tilde{\nu}$ = 3435, 2930, 1456, 1216, 1164, 1076, 1028, 863, 751, 699 cm^{-1}. HRMS (ESI): calcd. for $C_{22}H_{24}NO_4$[M + H] 366.1705; found 366.1710.

2-Indolyl-C-glucoside 7b: Following General Procedure F, the reaction was carried out between glucose-derived alkyne **4a** (18 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **7b** (20 mg, 90%) as a white solid. $[\alpha]_D^{20}$ = –6.57 (c = 1.85, $CHCl_3$); m.p. 161–165 °C. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.64 (br. s, 1 H), 7.60 (d, J = 7.8 Hz, 1 H), 7.37 (dd, J = 8.1, 0.7 Hz, 1 H), 7.19 (td, J = 7.8, 0.7 Hz, 1 H), 7.11 (td, J = 8.1, 1.0 Hz, 1 H), 6.48 (t, J = 1.0 Hz, 1 H), 6.09 (d, J = 3.7 Hz, 1 H), 5.48 (d, J = 2.6 Hz, 1 H), 4.67 (d, J = 3.7 Hz, 1 H), 4.34 (d, J = 2.6 Hz, 1 H), 1.81 (br. s, 1 H), 1.58 (s, 3 H), 1.37 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.22, 132.20, 128.25, 122.44, 120.78, 120.26, 112.27, 111.34, 105.01, 100.89, 100.17, 84.84, 78.02, 27.03, 26.36 ppm. IR (neat): $\tilde{\nu}$ = 3427, 2927, 2104, 1523, 1375, 1214, 1071, 1071, 754 cm^{-1}. HRMS (ESI): calcd. $C_{15}H_{18}NO_4$[M + H] 276.1236; found 276.1246.

2-Indolyl-*C*-riboside 7c: Following General Procedure F, the reaction was carried out between ribose-derived alkyne **4c** (19 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **7c** (22 mg, 95%) as an off-white solid. R_f = 0.45 (15% ethyl acetate in hexanes); m.p. 97–101 °C; $[\alpha]_D^{20}$ = –20.07 (c = 1.10, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.92 (br. s, 1 H), 7.57 (d, J = 7.7 Hz, 1 H), 7.33 (dd, J = 8.1, 0.6 Hz, 1 H), 7.18 (td, J = 7.7, 0.6 Hz, 1 H), 7.09 (td, J = 8.1, 1.0 Hz, 1 H), 6.45 (d, J = 1.6 Hz, 1 H), 5.47 (s, 1 H), 5.16 (s, 1 H), 4.85 (dd, J = 6.0, 0.6 Hz, 1 H), 4.79 (d, J = 6.0 Hz, 1 H), 3.44 (s, 3 H), 1.56 (s, 3 H), 1.33 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.9, 136.4, 128.3, 122.4, 120.9, 120.0, 112.9, 111.2, 110.5, 101.6, 85.8, 85.3, 84.2, 55.7, 26.6, 25.1 ppm. IR (neat): $\tilde{\nu}$ = 3372, 2930, 1738, 1456, 1217, 1095, 953, 872, 757, 668, 564 cm^{-1}. HRMS (ESI): calcd. for $C_{16}H_{19}NO_4$ [M + Na] 312.1212; found 312.1220.

2-Indolyl-C-riboside 7d: Following General Procedure F, the reaction was carried out between ribose-derived alkyne **4d** (30 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **7d** (19 mg, 83%) as a syrup. R_f = 0.25 (50% ethyl acetate in hexanes). $[\alpha]_D^{20}$ = –54.25 (c = 1.63, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.76 (br. s, 1 H), 7.60 (d, J = 7.9 Hz, 1 H), 7.38 (dd, J = 8.1, 0.8 Hz, 1 H), 7.18 (td, J = 7.9, 0.8 Hz, 1 H), 7.08 (td, J = 8.1, 1.0 Hz, 1 H), 6.53 (d, J = 1.3 Hz, 1 H), 5.21 (d, J = 3.4 Hz, 1 H), 4.83 (dd, J = 5.8, 3.4 Hz, 1 H), 4.75 (dd, J = 5.8, 1.4 Hz, 1 H), 4.28 (td, J = 5.6, 1.4 Hz, 1 H), 3.71 (d, J = 5.6 Hz, 2 H), 2.00 (br. s, 1 H), 1.62 (s, 3 H), 1.34 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.6, 132.9, 127.6, 122.4, 120.9, 119.8, 113.0, 111.3, 102.9, 84.6, 83.0, 82.6, 77.4, 62.3, 26.7, 24.7 ppm. IR (neat): $\tilde{\nu}$ = 3445, 2926, 2855, 1511, 1456, 1100, 910, 737 cm^{-1}. HRMS (ESI): calcd. for $C_{16}H_{20}NO_4$ [M + H] 290.1392; found 290.1390.

2-Indolyl-C-riboside α-7e: Following General Procedure F, the reaction was carried out between ribose-derived alkyne **4e** (31 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave α-**7e** (16.2 mg, 67%) as a syrup. R_f = 0.30 (50% ethyl acetate in hexanes). $[\alpha]_D^{20}$ = –45.57 (c = 0.46, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$),: δ = 8.65 (br. s, 1 H), 7.54 (d, J = 7.9 Hz, 1 H), 7.34 (dd, J = 7.9, 0.6 Hz, 1 H), 7.13 (td, J = 7.9, 0.6 Hz, 1 H), 7.07 (dt, J = 7.9, 1.2 Hz, 1 H), 6.30 (d, J = 1.1 Hz, 1 H), 4.69 (d, J = 6.5 Hz, 2 H), 4.25 (dd, J = 6.5, 4.6 Hz, 1 H), 4.19 (tt, J = 14.1, 7.0, 2.0 Hz, 1 H), 3.67–3.58 (m, 2 H), 3.17 (dd, J = 7.0, 2.0 Hz, 1 H), 1.80 (br. s, 1 H), 1.61 (s, 3 H), 1.45 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$),: δ = 136.2, 135.8, 128.6, 121.4, 120.0, 119.7, 113.0, 110.7, 101.0, 84.5, 82.7, 81.7, 81.4, 62.3, 28.7, 26.5, 25.3 ppm. IR (neat): $\tilde{\nu}$ = 3412, 2927, 1621, 1457, 1217, 1078, 757, 699 cm^{-1}. HRMS (ESI): calcd. for $C_{17}H_{22}NO_4$ [M + H] 304.1549; found 304.1559.

2-Indolyl-C-riboside 7f: Following General Procedure F, the reaction was carried out between ribose-derived alkyne **4f** (20 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **7f** (22 mg, 92%) as a syrup. $[\alpha]_D^{20}$ = +43.03 (c = 0.29, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.38 (br. s, 1 H), 7.57 (d, J = 7.8 Hz, 1 H), 7.37 (d, J = 8.2 Hz, 1 H), 7.19 (td, J = 7.8, 1.0 Hz, 1 H), 7.11 (td, J = 8.2, 0.9 Hz 1 H), 6.40 (s, 1 H), 5.32 (s, 1 H), 5.21 (d, J = 6.0 Hz, 1 H), 4.74 (dd, J = 6.0, 3.6 Hz, 1 H), 3.85 (td, J = 7.0, 3.6 Hz, 1 H), 2.68 (dd, J = 7.0, 2.6 Hz, 2 H), 2.01 (t, J = 2.6 Hz, 1 H), 1.58 (s, 3 H), 1.42 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$),: δ = 136.1, 135.0, 128.7, 128.3, 122.5, 120.6, 120.2, 113.1, 111.1, 100.3, 84.8, 81.0, 79.9, 79.4, 69.8, 26.3, 25.2, 18.7 ppm. IR (neat): $\tilde{\nu}$ = 3020, 1216, 1072, 758, 669 cm^{-1}. HRMS (ESI): calcd. for $C_{18}H_{20}NO_3$ [M + H] 298.1443; found 298.1451.

2-Indolyl-C-mannoside 7g: Following General Procedure F, the reaction was carried out between mannose-derived alkyne **4g** (19 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **7g** (20 mg, 86%) as a white solid. R_f = 0.45 (15% ethyl acetate in hexanes); m.p. 109–105 °C; $[\alpha]_D^{20}$ = –5.14 (c = 1.01, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.74 (br. s, 1 H), 7.60 (dd, J = 7.9, 0.9 Hz, 1 H), 7.37 (dd, J = 8.2, 0.9 Hz, 1 H), 7.18 (td, J = 7.9, 0.9 Hz, 1 H), 7.08 (td, J = 8.2, 0.9 Hz, 1 H), 6.56 (dd, J = 1.9, 0.7 Hz, 1 H), 5.17 (d, J = 3.2 Hz, 1 H), 5.00 (s, 1 H), 4.85 (dd, J = 5.7, 3.2 Hz, 1 H), 4.68 (d, J = 5.7 Hz, 1 H), 3.40 (s, 3 H), 1.60 (s, 3 H), 1.33 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.7, 132.4, 127.6, 122.4, 120.9, 119.8, 112.9, 111.3, 107.1, 103.2, 85.5, 81.8, 75.3, 55.1, 26.4, 24.6 ppm. IR (neat): $\tilde{\nu}$ = 3373, 2928, 2857, 1646, 1456, 1105, 1095, 660 cm^{-1}. HRMS (ESI): calcd. for $C_{16}H_{20}NO_4$ [M + H] 290.1392; found 290.1389.

2-Indolyl-C-mannoside 7h: Following General Procedure F, the reaction was carried out between mannose-derived alkyne **4h** (16 mg, 0.096 mmol) and *N*-tosyl-*o*-iodoaniline **5** (30 mg, 0.08 mmol). Column chromatography on silica gel gave the title compound **7h** (18 mg, 85%) as a white solid. R_f = 0.20 (10% ethyl acetate in hexanes); m.p. 142–147; $[\alpha]_D^{20}$ = –33.13 (c = 0.92, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.80 (br. s, 1 H), 7.59 (d, J = 7.9 Hz, 1 H), 7.37 (dd, J = 8.2, 0.6 Hz, 1 H), 7.18 (dt, J = 7.9, 0.6 Hz, 1 H), 7.08

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(td, J = 8.2, 0.8 Hz, 1 H), 6.55 (d, J = 1.28 Hz, 1 H), 4.91 (dd, J = 6.0, 4.0 Hz, 1 H), 4.82 (dd, J = 6.0, 3.3 Hz, 1 H), 4.65 (d, J = 3.3 Hz, 1 H), 4.13 (d, J = 10.7 Hz, 1 H), 3.36 (dd, J = 10.7, 4.0 Hz, 1 H), 1.62 (s, 3 H), 1.35 (s, 3 H) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.5, 132.6, 127.6, 122.3, 120.8, 119.7, 112.4, 111.3, 103.1, 82.3, 81.3, 78.3, 73.0, 26.4, 24.5 ppm. IR (neat): $\tilde{\nu}$ = 3394, 2931, 2104, 1620, 1215, 1101, 756 cm^{-1}. HRMS (ESI): calcd. for $C_{15}H_{18}NO_3$ [M + H] 260.1287; found 260.1275.

Supporting Information (see footnote on the first page of this article): Copies of ^{1}H and ^{13}C NMR spectra.

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