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C-Glycoside Clustering on Calix[4]arene, Adamantane, and Benzene Scaffolds through 1,2,3-Triazole Linkers

Alessandro Dondoni* and Alberto Marra*

Dipartimento di Chimica, Laboratorio di Chimica Organica, Università di Ferrara, Via L. Borsari 46, I-44100 Ferrara, Italy

adn@dns.unife.it

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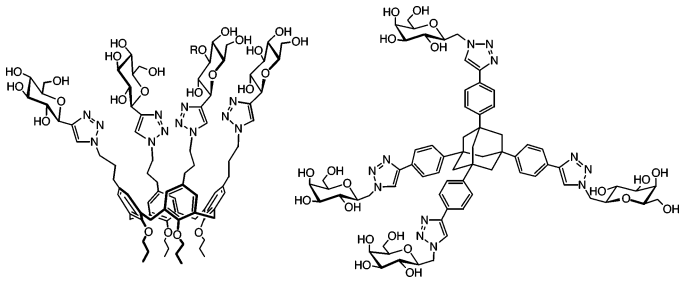

A route has been paved toward the preparation of triazole glycocluster libraries via the copper(I)-catalyzed modern version of the classical Huisgen 1,3-dipolar cycloaddition of azides to alkynes. Up to four 1,4-disubstituted 1,2,3-triazole rings bearing carbon-linked glycosyl fragments were constructed on various scaffolds via multiple cycloadditions of suitably polyfunctionalized calix[4]arene, adamantane, and benzene derivatives with ethynyl and azidomethyl *C*-glycosides. Each cycloaddition occurred with high regioselectivity to give exclusively the 1,4-disubstituted triazole ring in very high yield up to an average value of 98%. The high degree of efficiency of this approach and its wide scope constitute a simple and practical means for the attachment of various sugar units to polyfunctionalized substrates.

Introduction

The assembly of densely decorated scaffolds by carbohydrate residues has sparked significant interest in various research groups over the past 10 years or so.[1] Synthetic efforts were aimed at providing tools for a better understanding as well as modulating a major phenomenon called glycoside cluster effect[2] that operates in carbohydrate−protein interaction, the crucial process through which various intercellular communication and transduction events as well as the adhesion of bacteria and viruses to the cell surfaces take place.[3] It is widely accepted that nature compensates for the low intrinsic affinity of carbohydrate for proteins through the cooperative binding between multiple copies of ligands and receptors so that a strong adhesion results. However, according to an early definition of glycoside clustering,[4] the "affinity enhancement is much greater than would be expected from a simple effect of concentration increase." Although some attempts to quantify the effects of multivalent presentation have been reported,[5] the detailed mechanism at the molecular level still remains unclear. Thus, the design of various types of clusters that can serve as inhibitors of biological systems for medical use is still carried out on a very empirical basis. For example the works of Lee,[2b] Roy,[6] Lindorst,[7] Takahashi,[8] and their co-workers demonstrated that the cluster effect of synthetic compounds not only is related to the number and geometry of carbohydrate residues but also depends on their steric bulk and relative distances, as well as on the three-dimensional arrangement around the core, this disposition being in turn strictly determined by the nature of the scaffold itself and the linkers employed. Therefore, the synthesis of new kinds of glycoside clusters that will open the route to multivalent oligosaccharide libraries exibiting sugar number and variety, as well as scaffold and linker structure as diversity elements would offer new oportunities for studies of carbohydrate−protein recognition. It is in line with this concept that we report below the synthesis of various glycoside cluster arrays assembled on different scaffolds through the rigid and planar heteroaromatic triazole ring.

A plethora of linkers with flexible or rigid structures of variable length have been employed for glycocluster assembly on various scaffolds.[1] An efficient ligation technique such as that expressed by the so-called Sharpless "click chemistry" concept [9] and that based on the Huisgen 1,3-dipolar cycloaddition reactions of azides with alkynes to give 1,2,3-triazoles[10] has been exploited in only a few instances.[11] The discovery of

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copper(I) catalysis of this process that increased both effectivenes and selectivity, leading to the almost exclusive formation of the 1,4-disubstituted triazole ring,[12] and the remarkable stability of this heterocycle, not present in natural products, to metabolic transformations such as oxidation, reduction, and both basic and acid hydrolysis make this type of group connecting strategy a precious tool for bioorganic studies. However, most of the sugar alkynes employed by Santoyo−Gonzales[11a] were propargyl *O*-glycosides and therefore afforded *O*-glycosylated triazoles. Du[11b] exploited a 6-azidohexyl *O*-hexasaccharide derivative to prepare a single *O*-glycosylated triazole cluster. The weakness of the *O*-glycosidic bond to enzymatic and chemical degradations is well-known. The method of Wang[11c] and Roy[11d] was based on glycosyl azides and therefore led to easily hydrolyzable *N*-glycosyl triazole derivatives. Hence we decided to broaden and validate the scope of the click chemistry approach by performing the synthesis of triazole-based *C*-glycoclusters, i.e., systems in which glycosyl fragments are linked through an enzymatically and chemically resistant carbon−carbon bond to triazole rings supported on a scaffold. The approaches employed were based on the cycloaddition of an ethynyl and an azidomethyl *C*-glycoside to a multivalent centerpiece bearing azido or ethynyl groups, respectively. Hence, two structurally different types of *C*-glycoclusters were formed: one in which triazole rings attached to a scaffold were carrying a *C*-glycosyl residue at C-4 (left in Figure 1), the other in which the triazole rings beared a glycosylmethyl fragment at N-1 (right in Figure 1).

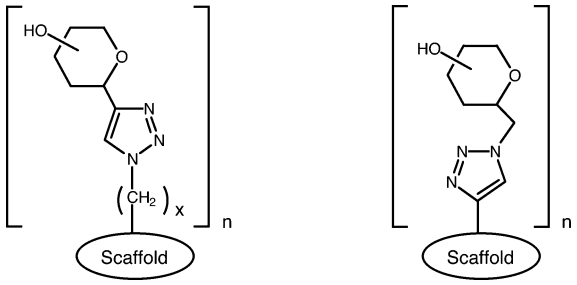

FIGURE 1. 1,4-Disubstituted triazole glycoclusters with C-4 (left) and N-1 (right) *C*-glycosyl linkages.

Results and Discussion

***C*-Glycoclusters from Multivalent Azido Substrates.** Various α- and *β*-linked ethynyl *C*-glycosides were available in our laboratory because of their use in synthetic approaches to *C*-glycosyl amino acid ethylene isosteres of sugar asparagines.[13] Moreover, in relation to our interest in glycocluster synthesis,[14] we recently reported on the synthesis of calix[4]arene *O*- and *C*-glycoconjugates (calixsugars), the former via multiple glycosylation of calix[4]arene polyols and the latter via Wittig olefination of calix[4]arene-derived polyaldehydes.[1a,15] However, the latter route to *C*-calixsugars showed some limitations in terms of both efficiency and scope due to the intrinsic difficulties of performing Wittig reactions in complex systems. Therefore

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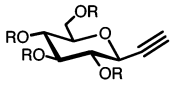
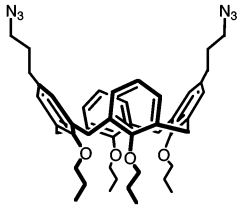
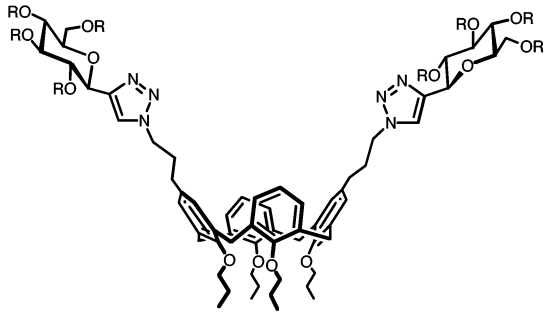
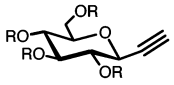
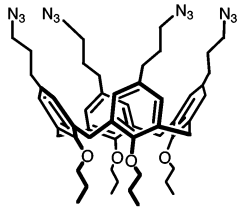
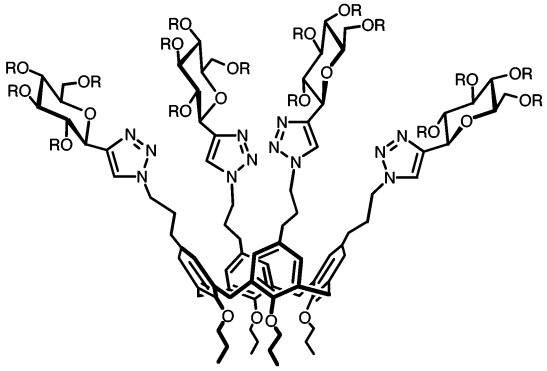
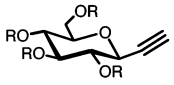
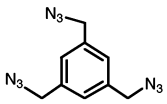
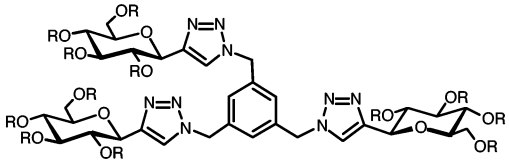
TABLE 1. Triazole *C*-Glycoclusters Prepared via Cycloaddition of Sugar Alkynes to Multivalent Azido Substrates[a]

Ethynyl Sugar	Substrate	Cluster	Yield (%)[b,c]
 **1a** R = Bn **1b** R = Ac	 **2**	 **3a** R = Bn **3b** R = Ac **3c** R = H	73 96 94
 **1a** R = Bn **1b** R = Ac	 **4**	 **5a** R = Bn **5b** R = Ac **5c** R = H	63 86 90
 **1a** R = Bn **1b** R = Ac	 **6**	 **7a** R = Bn **7b** R = Ac **7c** R = H	65 86 (92) 68

[a] Reaction conditions: ethynyl sugar (1.0 equiv), CuI, *i*-Pr_2EtN, toluene, 25 °C, 18 h. [b] Yields refer to isolated pure products. [c] Yields in parentheses refer to *O*-acetyl-protected compounds obtained from the *O*-benzylated derivatives via reaction with BCl_3 (CH_2Cl_2, −60 to 0 °C, 2 h) followed by acetylation (Ac_2O, Et_3N, rt, 18 h).

the synthesis of calix[4]arene *C*-glycoclusters by a new and efficient ligation strategy was the first target in our program. Hence we were delighted to observe that a stoichiometric amount (2.0 equiv) of ethynyl tetra-*O*-benzyl-*β*-D-glucopyranoside **1a**[13b,16] reacted regioselectively with the bis-azidopropyl tetrapropoxy-calix[4]arene **2**[17] in the presence of CuI and *i*-Pr_2-EtN in toluene at room temperature to generate the desired two 1,4-disubstituted 1,2,3-triazole rings, each one carrying a *β*-*C*-glucosyl residue at C-4, while N-1 was linked through a carbon tether to the upper rim of the calix[4]arene scaffold (Table 1). The high degree of efficiency of these 1,3-dipolar cycloadditions was substantiated by the fair yield (73%) of the bis-cycloadduct **3a** isolated by column chromatography. A similarly high-performing process occurred also between **1a** (4 equiv) and the tetra-azido calix[4]arene derivative **4**,[17] which by virtue of four concomitant alkyne-azide cycloaddition reactions afforded a *C*-glycosylated tetratriazole system anchored to the calix[4]arene upper ring. The isolated yield of the C_4-symmetric glycocluster **5a** (63%) indicated a 89% average yield for each cyloaddition reaction. Even higher degrees of efficiency were registered in the stoichiometric reactions of ethynyl tetra-*O*-acetyl-*β*-D-glucopyranoside **1b**[16a] with the same polyazido calix[4]arene derivatives **2** and **4**, which in fact afforded the corresponding *C*-glycosyl-calix[4]arenes **3b** and **5b** in 96% and 86% isolated yield, respectively (Table 1). Hence, in both cases each triazole-

(15) The realization by us that calix[4]arene derivatives can serve as convenient scaffolds for the synthesis of glycoclusters goes back to the mid-1990s. See: (a) Marra, A.; Scherrmann, M.-C.; Dondoni, A.; Casnati, A.; Minari, P.; Ungaro, R. *Angew. Chem., Int. Ed. Engl.* **1994**, *33*, 2479. (b) Marra, A.; Dondoni, A.; Sansone, F. *J. Org. Chem.* **1996**, *61*, 5155. (c) Dondoni, A.; Marra, A.; Scherrmann, M.-C.; Casnati, A.; Sansone, F.; Ungaro, R. *Chem. Eur. J.* **1997**, *3*, 1774.

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(17) Compounds **2** and **4** are new upper rim functionalized calix[4]arenes prepared from the corresponding polyols (ref 1a) and diphenyl phosphoryl azide in 86% and 89% yield, respectively.

forming cycloaddition reaction appeared to have occurred in almost quantitative manner. We suggest that the higher reactivity of **1b** with respect to **1a** is due to steric factors because the *O*-acetyl groups are less bulky than the *O*-benzyl groups and therefore give rise to a less encumbering array around the small ethynyl dipolarophile. The easily hydrolyzable *O*-acetyl groups in the sugar residues of the *C*-glycoclusters **3b** and **5b** make these products convenient precursors to free hydroxy compounds suitable for biological assays. In fact all acetyl groups of **3b** and **5b** were removed by treatment with 0.2 M NaOMe in MeOH at room temperature followed by neutralization with Amberlite IR-120 resin to give **3c** and **5c**, respectively. On the other hand, the exaustive debenzylation by catalytic hydrogenolysis of the sugar triazoles **3a** and **5a** resulted to be a quite difficult operation since only **3a** led to the expected hydroxy derivative **3c** upon repeated hydrogenation over $Pd(OH)_2$ (H_2, 7 bar, AcOH, 6 h). The tetra-triazole cluster **5b** failed to afford the corresponding hydroxy compound **5c** by hydrogenolysis under various conditions using Pd, Pt, and Rh as the catalyst. Moreover, the attempts to remove the benzyl groups in **3a** and **5a** by the use of BCl_3 in CH_2Cl_2 at low temperature, followed by acetylation, led to complex mixtures of products.

In line with the idea of exploring the viability of the triazole route to glycocluster libraries displaying different scaffolds as element of diversity, the assembly of D-glucose residues around benzene was investigated. Considering the nature of this core, this approach was expected to give rise to compact, rigid, and almost planar networks. Hence, both the *O*-benzyl and the *O*-acetyl sugar acetylenes **1a** and **1b** (3 equiv) were allowed to react with *sym*-tris(azidomethyl)benzene **6**[18] under the usual conditions (Table 1). These reactions afforded the expected C_3-symmetric *C*-glycocluters **7a** and **7b** in good isolated yields (Table 1) corresponding to an average yield of 86% and 90% for each highly regioselective azide-alkyne cycloaddition. In this series the acetylated glycocluster **7b** was also accessible in high yield (92%) by debenzylation with BCl_3 of **7a** followed by standard acetylation. The product obtained by this two-step reaction sequence was identical in all respects to that obtained by the more direct route starting from **1b**. The peracetate **7b** was in turn converted into the free hydroxy compound **7c** via the above-mentioned deacetylation procedure.

***C*-Glycoclusters from Multivalent Ethynyl Substrates.** The azide-alkyne cycloaddition approach to regioisomeric triazole *C*-glycoclusters was then considered by reacting azidomethyl *C*-glycosides (Table 2) with multivalent ethynyl substrates. The change of cycloaddition partners was aimed at introducing another element of diversity in the structure of the target *C*-glycoclusters, i.e., the attachment of the sugar residues to N-1 of the triazole ring through a methylene bridge instead of the direct binding to C-4 as in the examples reported in Table 1. In this approach we first examined the reaction of azidomethyl tetra-*O*-benzyl-β-D-glucopyranoside **8a**[19] and its acetylated derivative **8b**[19] with *sym*-triethynylbenzene **9**[20] in the presence of the usual catalyst CuI/*i*-Pr_2EtN in toluene. Initial experiments showed that more forcing conditions than in the previous approach were required to complete the multiple cycloaddition scheme on the trivalent ethynyl substrate. Hence an excess of azido sugar (1.5 equiv per ethynyl group) was employed and the temperature was raised to 80 °C. Under these conditions the tripodal clusters **10a** and **10b** bearing glucosylmethyl residues at N-1 were obtained in good (68%) and excellent (96%) isolated yields, respectively. Most of the excess of sugars **8a** and **8b** was recovered by chromatography of the crude reaction mixtures. Also in these systems, the alternative approach to the valuable *C*-glycocluster **10b** featuring *O*-acetyl protective groups in the chain-end sugar moieties was effectively carried out by $BeCl_3$-promoted debenzylation of **10a** and subsequent acetylation. Then, the free hydroxy compound **10c** was easily generated from **10b** by the usual treatment with NaOMe in MeOH. The change of the sugar fragment in the cycloaddition with **9** was studied by using the galactose azidomethyl derivatives **11a** (*O*-benzyl protection)[19] and **11b** (*O*-acetyl protection)[19] under the same conditions described above. The corresponding trivalent *C*-galactosyl clusters **12a** and **12b** were typically isolated in yields comparable to those of the *C*-glucosyl isomers **10a** and **10b**. The acetylated product **12b** was obtained from the benzylated derivative **12a** in good isolated yield (84%) as was the free hydroxy derivative **12c** prepared from **12b**.

Multiple 1,3-dipolar cycloadditions under the same conditions described above were employed to prepare the tetravalent triazole *C*-glycoclusters **14a,b** and **16a,b** on calix[4]arene and adamantane scaffolds, respectively, using tetraethynyl-calix[4]-arene **13**[21] and tetrakis(4-ethynylphenyl)-adamantane **15**[22] as multivalent dipolarophiles (Table 2). Each of these processes showed high degree of efficiency as substantiated by the yields of isolated *O*-benzyl and *O*-acetyl *C*-glycoclusters **14a,b** and **16a,b**. The free hydroxy compounds **14c** and **16c** were obtained by the usual hydrolysis of the corresponding acetylated derivatives **14b** and **16b**. The spatial disposition of four sugar-bearing arms in the calix[4]arene scaffolded compounds **14a**−**c** may vary owing to some flexibility of the macrocycle ring whereas that in the adamantane scaffolded compounds **16a**−**c** should be fixed in a rigid tetrahedral arrangement as shown.

Structure Determination. The NMR analysis provided evidence for the structural assignment of all of the above *C*-glycoclusters prepared. The conservation of the original β-D-configuration of each glycoside fragment was confirmed by the large vicinal coupling constants (ca. 9.5 Hz) observed for the anomeric hydrogen atoms, as expected for trans-diaxal H-1 and H-2 protons in pyranoses adopting a $^4C_1$ conformation. Moreover, the fixed cone conformation of the calix[4]arene scaffold was substantiated by the presence of signals for the equatorial and axial protons of the methylene bridges as doublets at ca. 3

(18) (a) Heyer, D.; Lehn, J.-M. *Tetrahedron Lett*. **1986**, *27*, 5869. (b) Garrett, T. M.; McMurry, T. J.; Hosseini, M. W.; Reyes, Z. E.; Hahn, F. E.; Raymond, K. N. *J. Am. Chem. Soc*. **1991**, *113*, 2965.

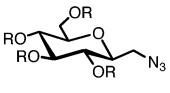
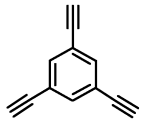
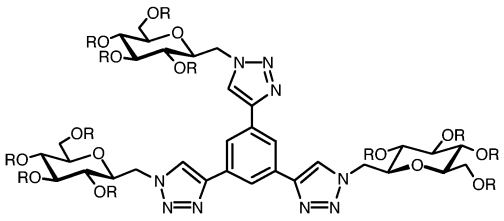
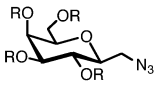
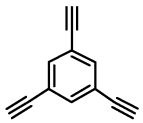
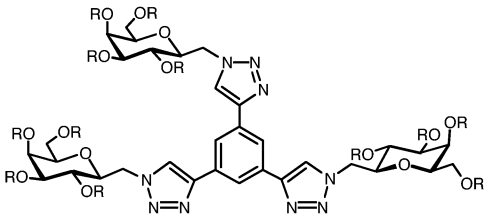
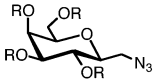
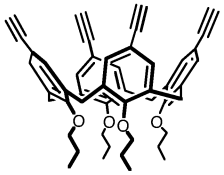
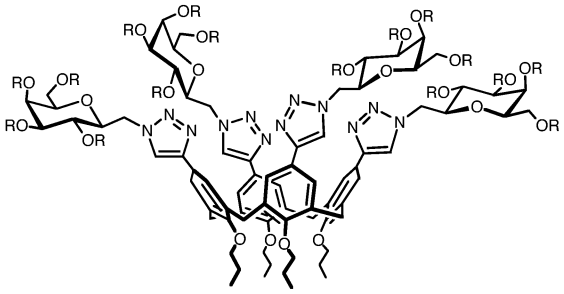
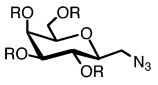
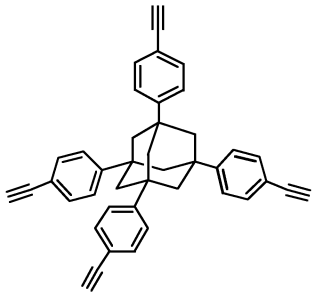
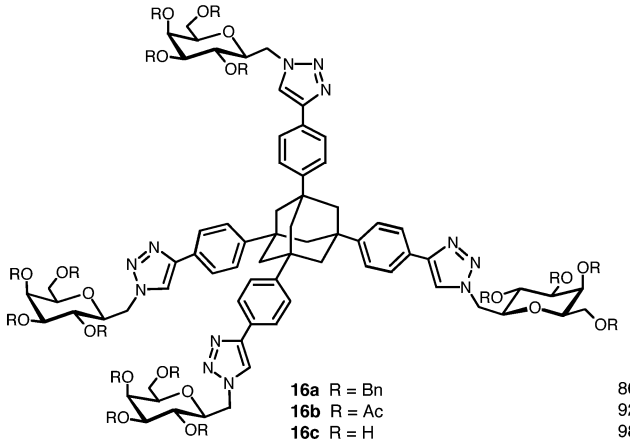
(19) The benzylated glucopyranosyl derivative **8a** was reported in the literature without experimental and physical data (Lockhoff, O. *Angew. Chem., Int. Ed.* **1998**, *37*, 3436). We have prepared and fully characterized **8a** as described for the known galactopyranosyl isomer **11a** (Dondoni, A.; Massi, A.; Sabbatini, S.; Bertolasi, V. *J. Org. Chem*. **2002**, *67*, 6979). The acetylated derivatives **8b** and **11b** were prepared from **8a** and **11a**, respectively, by debenzylation with BCl_3 and acetylation with Ac_2O-pyridine.

(20) Known 1,3,5-triethynylbenzene (Hübel, W.; Merényi, R. *Angew. Chem*. **1962**, *74*, 781) was prepared from 1,3,5-tribromobenzene as decribed; see: Wang, F.; Kaafarani, B. R.; Neckers, D. C. *Macromolecules* **2003**, *36*, 8225.

(21) Tetraethynyl-tetrapropoxy-calix[4]arene **13** was obtained by Sonogashira−Heck−Cassar cross-coupling reaction of the corresponding upper rim tetraiodo derivative (Arduini, A.; Giorgi, G.; Pochini, A.; Secchi, A.; Ugozzoli, F. *J. Org. Chem*. **2001**, *66*, 8302) with trimethylsilylacetylene in the presence of $PdCl_2(PPh_3)_2$ and CuI as described for the synthesis of the tetraethynyl-tetrakis(2-ethoxyethoxy)-calix[4]arene analogue (Arduini, A.; Pochini, A.; Sicuri, A. R.; Secchi, A.; Ungaro, R. *Gazz. Chim. Ital*. **1994**, *124*, 129).

(22) Galoppini, E.; Gilardi, R. *Chem. Commun*. **1999**, 173.

TABLE 2. Triazole *C*-Glycoclusters Prepared via Cycloaddition of Azidomethyl Glycosides to Multivalent Ethynyl Substrates[a]

Azido Sugar	Substrate	Cluster	Yield (%)[b,c]
			
8a R = Bn **8b** R = Ac	**9**	**10a** R = Bn **10b** R = Ac **10c** R = H	68 96 (88) 90
			
11a R = Bn **11b** R = Ac	**9**	**12a** R = Bn **12b** R = Ac **12c** R = H	62 82 (84) 88
			
11a R = Bn **11b** R = Ac	**13**	**14a** R = Bn **14b** R = Ac **14c** R = H	61 83 (91) 96
			
11a R = Bn **11b** R = Ac	**15**	**16a** R = Bn **16b** R = Ac **16c** R = H	80 92 (95) 98

[a] Reaction conditions: azido sugar (1.5 equiv), CuI, *i*-Pr_2EtN, toluene, 80 °C, 18 h (48 h for **10a** and **12a**). [b] Yields refer to isolated pure products. [c] Yields in parentheses refer to *O*-acetyl-protected compounds obtained from the *O*-benzylated derivatives via reaction with BCl_3 (CH_2Cl_2, −60 to 0 °C, 2 h) followed by acetylation (Ac_2O, Et_3N, rt, 18 h).

and 4 ppm, respectively.[23] On the other hand, the regioisomeric assignment of the disubstituted 1,2,3-triazole rings was less straightforward. In fact, the well-known empirical rule[12a,24] stating that the H-5 proton in 1,4-disubstituted triazoles resonates always downfield compared to the H-4 proton in the corresponding 1,5-isomer, could not be employed because triazole rings in all *C*-glycoclusters formed as single regioisomers.

(23) Iqbal, M.; Mangiafico, T.; Gutsche, C. D. *Tetrahedron* **1987**, *43*, 4917.

(24) (a) Alonso, G.; García-López, M. T.; García-Muñoz, G.; Madroñero, R.; Rico, M. *J. Heterocycl. Chem.* **1970**, *7*, 1269. (b) Crandall, J. K.; Crawley, L. C.; Komin, J. B. *J. Org. Chem.* **1975**, *40*, 2045. (c) Wang, Z.-X.; Qin, H.-L. *Chem. Commun.* **2003**, 2450.

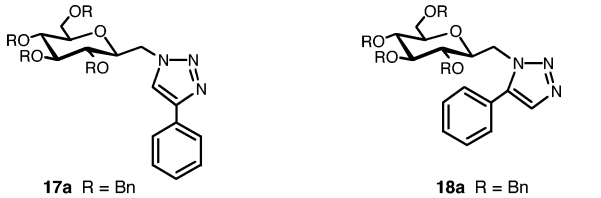


FIGURE 2. Monovalent 1,4- and 1,5-disubstituted triazole derivatives prepared by cycloaddition of azidomethyl *C*-glucosides **8a,b** with phenylacetylene.

Therefore, NOE experiments were performed for the acetylated *C*-glycoclusters since all these compounds displayed clear first-order ^{1}H NMR spectra. Unfortunately, only the NMR spectra of **3b** and **7b** (Table 1) showed significant NOEs between the triazole proton and both the methylene group linked to the triazole N-1 atom and the H-2 pyranose proton. This proximity relationship indicated a 1,4-disubstitution pattern for the heterocyclic units in **3b** and **7b**. To circumvent the absence of diagnostic NOEs in all clusters bearing the sugar moieties onto N-1 of triazole rings, i.e. **10**, **12**, **14**, and **16** (Table 2), we decided to synthesize two pairs of regioisomeric model compounds and then compare their spectroscopic data. Hence, the monovalent 1,4- and 1,5-disubstituted 1,2,3-triazole derivatives **17a**,**b** and **18a**,**b** (Figure 2) were prepared by cycloaddition of the azidomethyl *C*-glucosides **8a**,**b** with phenylacetylene in the presence of CuI or $CpRuCl(PPh_3)_2$ as the catalyst, respectively.[25] The ^{1}H NMR analysis of these products revealed that the triazole proton of both benzylated sugar **17a** (8.00 ppm) and acetylated sugar **17b** (7.94 ppm) that formed in the presence of CuI and *i*-Pr_2EtN resonated at lower field than the triazole proton of compounds **18a** and **18b** derived from the ruthenium-promoted cycloaddition (7.70 and 7.71 ppm, respectively). These data were in agreement with the above-mentioned NMR rule[12a,24] and therefore proved the structure assigned to the regioisomer pairs **17a**,**b** and **18a**,**b** on the basis of the reaction mechanisms proposed in the literature.[12,25] Reasonably, it can be deduced that all *C*-glycoclusters synthesized from sugar azides **8a**,**b** and **11a**,**b** by copper-mediated cycloaddition feature 1,4-disubstituted triazole moieties. Moreover, in agreement with previous observations made by us[26] and others,[27] large $\Delta(\delta_{C4} - \delta_{C5})$ values (ca. 26 ppm) were found for the triazole carbon atoms in the ^{13}C NMR spectra of **17a** ($\delta_{C4} = 147.7$ ppm; $\delta_{C5} = 121.4$ ppm) and **17b** ($\delta_{C4} = 147.9$ ppm; $\delta_{C5} = 121.5$ ppm). On the other hand, the 1,5-disubstituted isomers **18a**,**b** exhibited negative and significantly smaller $\Delta(\delta_{C4} - \delta_{C5})$ values (ca. −7 ppm) for the corresponding carbon atoms (**18a**: $\delta_{C4} = 132.8$ ppm; $\delta_{C5} = 139.5$ ppm. **18b**: $\delta_{C4} = 132.9$ ppm; $\delta_{C5} = 139.5$ ppm).[28] The *O*-benzylated sugar clusters **10a** and **12a**,[29] that appear to be the *C*-glycoclusters structurally more similar to the model compound **17a**, as well as the whole series of acetylated *C*-glycoclusters reported in Tables 1 and 2, displayed in their ^{13}C NMR spectra $\Delta(\delta_{C4} - \delta_{C5})$ values in the range 21.7−27.0 ppm (see Experimental Section). This finding made it possible to firmly establish the 1,4-disubstituted structure for the 1,2,3-triazole rings of all the *C*-glycoclusters prepared without the need for direct comparison with the corresponding regioisomers as required by the ^{1}H NMR-based rule.[12a,24]

Conclusions

In conclusion, an alkyne-azide cycloaddition based route to various *C*-glycoclusters featuring 1,2,3-triazole rings as linkers and different scaffolds has been developed. Having established the high degree of efficiency and tolerance of this reaction to various changes in both the functionalized sugars and the multivalent substrates, this route should be viable for the preparation of a rich collection of this class of glycoclusters.

Experimental Section

All moisture-sensitive reactions were performed under a nitrogen atmosphere using oven-dried glassware. Anhydrous solvents were dried over standard drying agents[30] and freshly distilled prior to use. Reactions were monitored by TLC on silica gel 60 F_{254} with detection by charring with sulfuric acid. Flash column chromatography[31] was performed on silica gel 60 (230−400 mesh). Melting points were determined with a capillary apparatus. Optical rotations were measured at 20 ± 2 °C in the stated solvent; $[\alpha]_D$ values are given in deg·mL·g^{-1}.dm^{-1}. ^{1}H NMR (300 and 400 MHz) and ^{13}C NMR spectra (75 and 100 MHz) were recorded for $CDCl_3$ solutions at room temperature unless otherwise specified. Peak assignments were aided by ^{1}H−^{1}H COSY and gradient-HMQC experiments. In the ^{1}H NMR spectra reported below, the *n* and *m* values quoted in geminal or vicinal proton−proton coupling constants $J_{n,m}$ refer to the number of the corresponding sugar protons. MALDI-TOF mass spectra were acquired using 2,5-dihydroxy-benzoic acid as the matrix.

5,17-Bis(3-azidopropyl)-25,26,27,28-tetrapropoxy-calix[4]-arene (2). A mixture of known[1a] 5,17-bis(3-hydroxypropyl)-25,26,27,28-tetrapropoxy-calix[4]arene (355 mg, 0.50 mmol), sodium azide (130 mg, 2.00 mmol), diphenyl phosphoryl azide (320 μL, 1.50 mmol), 1,8-diazabicyclo[5.4.0.]undec-7-ene (150 μL, 1.00 mmol), and anhydrous DMF (2.5 mL) was stirred at 120 °C for 14 h, then cooled to room temperature, diluted with Et_2O (100 mL), washed with H_2O (2 × 10 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel with 15:1 cyclohexane/AcOEt to give **2** (327 mg, 86%) as a white solid. Mp 169−170 °C (cyclohexane/pentane). ^{1}H NMR (300 MHz): δ 6.60 (s, 4H, Ar), 6.55−6.45 (m, 6H, Ar), 4.44 and 3.12 (2d, 8H, J = 13.2 Hz, 4 ArCH_2Ar), 3.92−3.80 (m, 8H, 4 $CH_3CH_2CH_2O$), 3.22 (t, 4H, J = 6.8 Hz, 2 $CH_2CH_2CH_2N_3$), 2.46 (t, 4H, J = 7.5 Hz, 2 $CH_2CH_2CH_2N_3$), 2.02−1.88 (m, 8H, 4 $CH_3CH_2CH_2O$), 1.78 (tt, 4H, J = 6.8, 7.5 Hz, 2 $CH_2CH_2CH_2N_3$), 1.04 and 0.98 (2t, 12H, J = 7.5 Hz, 4 $CH_3CH_2CH_2O$). ^{13}C NMR (75 MHz): δ 156.1 (C), 155.3 (C), 135.4 (C), 134.6 (C), 133.7 (C), 128.2 (CH), 127.8 (CH), 122.0 (CH), 76.7 (CH_2), 50.7 (CH_2), 32.1 (CH_2), 31.0 (CH_2), 30.6 (CH_2), 23.3 (CH_2), 23.2 (CH_2), 10.4 (CH_3), 10.2 (CH_3). Anal. Calcd for $C_{46}H_{58}N_6O_4$: C, 72.79; H, 7.70; N, 11.07. Found: C, 72.49; H, 7.54; N, 10.80.

5,17-Bis{3-[4-(2,3,4,6-tetra-*O*-benzyl-β-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]propyl}-25,26,27,28-tetrapropoxy-calix[4]-arene (3a). A mixture of calix[4]arene diazide **2** (76 mg, 0.10 mmol), sugar acetylene **1a** (110 mg, 0.20 mmol), freshly distilled

(25) Recently, Fokin and Jia and co-workers described the highly 1,5-regioselective cycloaddition of alkynes and azides in the presence of ruthenium complexes; see: Zhang, L.; Chen, X.; Xue, P.; Sun, H. H. Y.; Williams, I. D.; Sharpless, K. B.; Fokin, V. V.; Jia, G. *J. Am. Chem. Soc.* **2005**, *127*, 15998.

(26) Dondoni, A.; Giovannini, P. P.; Massi, A. *Org. Lett*. **2004**, *6*, 2929.

(27) (a) Rodios, N. A. *J. Heterocycl. Chem.* **1984**, *21*, 1169. (b) Hoffmann, B.; Bernet, B.; Vasella, A. *Helv. Chim. Acta* **2002**, *85*, 265.

(28) For ^{13}C NMR data of simple 1,4- and 1,5-disubstituted triazoles, see: Wamhoff, H. In *Comprehensive Heterocyclic Chemistry*; Potts, K. T., Ed.; Pergamon Press: Oxford, 1984; Vol. 5, pp 680−683.

(29) The complexity of the ^{13}C NMR spectra recorded for the other benzylated *C*-glycoclusters prevented the unambiguous assignment of the triazole carbon atoms.

(30) Armarego, W. L. F.; Chai, C. L. L. *Purification of Laboratory Chemicals*, 5th ed.; Butterworth-Heinemann, Amsterdam, 2003.

(31) Still, W. C.; Kahn, M.; Mitra, A. *J. Org. Chem.* **1978**, *43*, 2923.

N,*N*-diisopropylethylamine (175 μL, 1.00 mmol), CuI (9.5 mg, 0.05 mmol), and anhydrous toluene (2 mL) was sonicated in an ultrasound cleaning bath for 1 min, then magnetically stirred in the dark at room temperature for 18 h, diluted with AcOEt (100 mL), washed with 1 M phosphate buffer at pH 7 (2 × 10 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel with 2:1 cyclohexane/AcOEt to give **3a** (136 mg, 73%) as a white foam; $[\alpha]_D = +3.9$ (*c* 1.0, $CHCl_3$). ^{1}H NMR (400 MHz): δ 7.36−7.24 and 7.18−7.14 (2m, 38H, Ar, 2 H-5 Tr.), 7.01−6.97 (m, 4H, Ar), 6.55 and 6.53 (2d, 4H, *J* = 1.8 Hz, Ar calix.), 6.49−6.47 (m, 6H, Ar calix.), 4.96 and 4.91 (2d, 4H, *J* = 11.2 Hz, 2 PhCH_2), 4.86 and 4.57 (2d, 4H, *J* = 10.8 Hz, 2 PhCH_2), 4.64 and 4.32 (2d, 4H, *J* = 10.8 Hz, 2 PhCH_2), 4.56 and 4.51 (2d, 4H, *J* = 12.4 Hz, 2 PhCH_2), 4.54 (d, 2H, $J_{1,2}$ = 9.8 Hz, 2 H-1), 4.42 and 4.41 (2d, 4H, *J* = 13.2 Hz, 4 H_{ax} of ArCH_2Ar), 4.16 and 4.05 (2dt, 4H, *J* = 7.2, 13.8 Hz, 2 ArCH$_2$CH$_2$CH_2), 3.99 (dd, 2H, $J_{2,3}$ = 9.0 Hz, 2 H-2), 3.87−3.79 (m, 8H, 4 CH$_3$CH$_2$CH_2O), 3.83 (dd, 2H, $J_{3,4}$ = 9.0 Hz, 2 H-3), 3.75 (dd, 2H, $J_{5,6a}$ = 1.8, $J_{6a,6b}$ = 10.8 Hz, 2 H-6a), 3.72 (dd, 2H, $J_{4,5}$ = 9.6 Hz, 2 H-4), 3.70 (dd, 2H, $J_{5,6b}$ = 4.5 Hz, 2 H-6b), 3.65 (ddd, 2H, 2 H-5), 3.09 and 3.08 (2d, 4H, *J* = 13.2 Hz, 4 H_{eq} of ArCH_2Ar), 2.34 and 2.26 (2dt, 4H, *J* = 7.2, 14.0 Hz, 2 ArCH_2CH$_2$CH$_2$), 2.02 (tt, 4H, *J* = 7.2, 7.2 Hz, 2 ArCH$_2$CH_2CH$_2$), 1.97−1.88 (m, 8H, 4 CH$_3$CH_2CH$_2$O), 1.02 and 0.98 (2t, 12H, *J* = 7.5 Hz, 4 CH_3CH$_2$CH$_2$O). ^{13}C NMR (75 MHz): δ 156.1 (C), 155.4 (C), 145.4 (C), 138.6 (C), 138.0 (C), 135.4 (C), 134.6 (C), 133.0 (C), 128.4 (CH), 128.3 (CH), 128.2 (CH), 128.0 (CH), 127.8 (CH), 127.7 (CH), 127.6 (CH), 123.0 (CH), 122.1 (CH), 86.9 (CH), 81.8 (CH), 79.4 (CH), 78.2 (CH), 76.6 (CH_2), 75.6 (CH_2), 75.1 (CH_2), 74.8 (CH_2), 74.0 (CH), 73.4 (CH_2), 69.2 (CH_2), 49.3 (CH_2), 31.8 (CH_2), 31.7 (CH_2), 30.9 (CH_2), 23.2 (CH_2), 23.1 (CH_2), 10.4 (CH_3), 10.2 (CH_3). MALDI-TOF MS (1856.38): 1858.5 (M^+ + 2H), 1880.5 (M^+ + H + Na), 1896.5 (M^+ + H + K). Anal. Calcd for $C_{118}H_{130}N_6O_{14}$: C, 76.37; H, 7.06; N, 4.53. Found: C, 76.10; H, 6.91; N, 4.33.

5,17-Bis{3-[4-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]propyl}-25,26,27,28-tetrapropoxy-calix[4]-arene (3b). The cycloaddition between diazide **2** (76 mg, 0.10 mmol) and alkyne **1b** (71 mg, 0.20 mmol) was carried out as described for the preparation of **3a** to give, after column chromatography on silica gel (2.5:1 AcOEt/cyclohexane), **3b** (141 mg, 96%) as a syrup; $[\alpha]_D = -22.5$ (*c* 1.0, $CHCl_3$). ^{1}H NMR (400 MHz, C_6D_6): δ 7.06 (s, 2H, 2 H-5 Tr.), 6.74−6.68 (m, 6H, Ar), 6.63−6.60 (m, 4H, Ar), 5.56−5.50 (m, 4H, 2 H-2, 2 H-3), 5.50−5.44 (m, 2H, 2 H-4), 4.81−4.76 (m, 2H, 2 H-1), 4.55 (d, 4H, *J* = 13.0 Hz, 4 H_{ax} of ArCH_2Ar), 4.39 (dd, 2H, $J_{5,6a}$ = 4.5, $J_{6a,6b}$ = 12.6 Hz, 2 H-6a), 3.97 (dd, 2H, $J_{5,6b}$ = 2.2 Hz, 2 H-6b), 3.89−3.85 (m, 4H, 2 CH$_3$CH$_2$CH_2O), 3.79 (t, 4H, *J* = 7.3 Hz, 2 CH$_3$CH$_2$CH_2O), 3.67 and 3.60 (2dt, 4H, *J* = 7.0, 13.8 Hz, 2 ArCH$_2$-CH$_2$CH_2), 3.31 (ddd, 2H, $J_{4,5}$ = 9.5 Hz, 2 H-5), 3.20 and 3.19 (2d, 4H, *J* = 13.0 Hz, 4 H_{eq} of ArCH_2Ar), 2.14−2.02 (m, 4H, 2 ArCH_2-CH$_2$CH$_2$), 1.97−1.84 (m, 8H, 4 CH$_3$CH_2CH$_2$O), 1.71, 1.68, 1.67, and 1.64 (4s, 24H, 8 Ac), 1.70−1.63 (m, 4H, 2 ArCH$_2$CH_2CH$_2$), 0.91 and 0.86 (2t, 12H, *J* = 7.5 Hz, 4 CH_3CH$_2$CH$_2$O). ^{1}H NMR (400 MHz, $CDCl_3$) selected data: δ 7.54 (s, 2H, 2 H-5 Tr.), 6.55 (s, 4H, Ar), 6.49−6.46 (m, 6H, Ar), 5.36 (dd, 2H, $J_{2,3}$ = 9.4, $J_{3,4}$ = 9.0 Hz, 2 H-3), 5.30 (dd, 2H, $J_{1,2}$ = 9.5 Hz, 2 H-2), 5.19 (dd, 2H, $J_{4,5}$ = 9.9 Hz, 2 H-4), 4.79 (d, 2H, 2 H-1), 4.42 and 3.10 (2d, 8H, *J* = 13.2 Hz, 4 ArCH_2Ar), 4.30 (dd, 2H, $J_{5,6a}$ = 5.0, $J_{6a,6b}$ = 12.8 Hz, 2 H-6a), 4.23−4.15 (m, 4H, 2 ArCH$_2$CH$_2$CH_2), 4.12 (dd, 2H, $J_{5,6b}$ = 2.0 Hz, 2 H-6b), 3.88 (ddd, 2H, 2 H-5). ^{13}C NMR (75 MHz): δ 170.6, 170.2, and 169.5 (CO), 156.1 and 155.5 (C Ar), 143.9 (C-4 Tr.), 135.5, 134.5, and 133.0 (C Ar), 128.1 and 127.8 (CH Ar), 122.2 (C-5 Tr.), 122.0 (CH Ar), 76.7 (CH$_3$CH$_2$CH_2O), 76.2 (CH), 74.0 (CH), 73.4 (CH), 71.2 (CH), 68.4 (CH), 62.1 (C-6), 49.7 (ArCH$_2$CH$_2$CH_2), 31.8 (CH_2), 31.7 (CH_2), 30.9 (CH_2), 23.2 (CH_2), 23.1 (CH_2), 20.7 and 20.6 (CH_3CO), 10.4 and 10.1 (CH_3-CH$_2$CH$_2$O). MALDI-TOF MS (1471.68): 1473.3 (M^+ + H), 1496.2 (M^+ + H + Na), 1511.2 (M^+ + K). Anal. Calcd for $C_{78}H_{98}N_6O_{22}$: C, 63.66; H, 6.71; N, 5.71. Found: C, 63.39; H, 6.60; N, 5.56.

5,17-Bis{3-[4-(β-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]-propyl}-25,26,27,28-tetrapropoxy-calix[4]arene (3c). A solution of **3b** (29 mg, 0.02 mmol) in a 0.2 M solution of NaOMe in MeOH (4 mL, prepared from Na and MeOH immediately before the use) was kept at room temperature for 2 h in a nitrogen atmosphere, then neutralized with Amberlite IR-120 resin (H^+ form, activated and washed with H_2O and MeOH immediately before the use), and filtered through a sintered glass filter. The resin was washed with MeOH, and the solution was concentrated and dried under high vacuum to give **3c** (21 mg, 94%) as an amorphous solid; $[\alpha]_D = +6.6$ (*c* 1.0, MeOH). ^{1}H NMR (300 MHz, CD_3OD): δ 7.84 (bs, 2H, 2 H-5 Tr.), 6.75 (d, 4H, *J* = 7.5 Hz, Ar), 6.64 (t, 2H, *J* = 7.5 Hz, Ar), 6.45 (s, 4H, Ar), 4.48 and 3.14 (2d, 8H, *J* = 13.2 Hz, 4 ArCH_2Ar), 4.46−4.42 (m, 2H, 2 H-1), 4.18 (t, 4H, *J* = 6.7 Hz, 2 ArCH$_2$CH$_2$CH_2), 3.93 (t, 4H, *J* = 7.5 Hz, 2 CH$_3$CH$_2$CH_2O), 3.92−3.88 (m, 2H, 2 H-6a), 3.81 (t, 4H, *J* = 7.5 Hz, 2 CH$_3$CH$_2$CH_2O), 3.71 (dd, 2H, $J_{5,6b}$ = 4.0, $J_{6a,6b}$ = 12.0 Hz, 2 H-6b), 3.66−3.42 (m, 8H), 2.16 (t, 4H, *J* = 7.0 Hz, 2 ArCH_2CH$_2$CH$_2$), 2.08−1.90 (m, 12H, 4 CH$_3$CH_2CH$_2$O, 2 ArCH$_2$CH_2CH$_2$), 1.06 and 1.03 (2t, 12H, *J* = 7.5 Hz, 4 CH_3CH$_2$CH$_2$O). ^{13}C NMR (75 MHz, CD_3OD): δ 157.8 (C), 156.1 (C), 147.2 (C), 136.5 (C), 135.9 (C), 134.9 (C), 129.4 (CH), 129.2 (CH), 124.9 (CH), 123.2 (CH), 82.2 (CH), 79.6 (CH), 78.1 (CH_2), 77.8 (CH_2), 75.6 (CH), 75.0 (CH), 71.6 (CH), 63.0 (CH_2), 50.7 (CH_2), 32.9 (CH_2), 32.7 (CH_2), 31.9 (CH_2), 24.5 (CH_2), 24.4 (CH_2), 10.9 (CH_3), 10.7 (CH_3). MALDI-TOF MS (1135.38): 1136.5 (M^+ + H), 1158.5 (M^+ + Na), 1174.5 (M^+ + K). Anal. Calcd for $C_{62}H_{82}N_6O_{14}$: C, 65.59; H, 7.28; N, 7.40. Found: C, 65.30; H, 7.19; N, 7.25.

5,11,17,23-Tetrakis(3-azidopropyl)-25,26,27,28-tetrapropoxy-calix[4]arene (4). A mixture of known[1a] 5,11,17,23-tetrakis(3-hydroxypropyl)-25,26,27,28-tetrapropoxy-calix[4]arene (412 mg, 0.50 mmol), sodium azide (260 mg, 4.00 mmol), diphenyl phosphoryl azide (640 μL, 3.00 mmol), 1,8-diazabicyclo[5.4.0.]undec-7-ene (300 μL, 2.00 mmol), and anhydrous DMF (5 mL) was stirred at 120 °C for 14 h, then cooled to room temperature, diluted with Et_2O (150 mL), washed with H_2O (2 × 10 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel with 9:1 cyclohexane/AcOEt to give **4** (412 mg, 89%) as a syrup. ^{1}H NMR (300 MHz): δ 6.47 (s, 8H, Ar), 4.42 and 3.08 (2d, 8H, *J* = 13.0 Hz, 4 ArCH_2Ar), 3.86−3.81 (m, 8H, 4 CH$_3$-CH$_2$CH_2O), 3.18 (t, 8H, *J* = 6.8 Hz, 4 CH$_2$CH$_2$CH_2N$_3$), 2.39 (t, 8H, *J* = 7.5 Hz, 4 CH_2CH$_2$CH$_2$N$_3$), 2.02−1.89 (m, 8H, 4 CH$_3$CH_2-CH$_2$O), 1.73 (tt, 8H, *J* = 6.8, 7.5 Hz, 4 CH$_2$CH_2CH$_2$N$_3$), 1.00 (t, 12H, *J* = 7.5 Hz, 4 CH_3CH$_2$CH$_2$O). ^{13}C NMR (75 MHz): δ 154.8 (C), 134.7 (C), 133.8 (C), 128.0 (CH), 76.8 (CH_2), 50.6 (CH_2), 32.0 (CH_2), 30.9 (CH_2), 30.5 (CH_2), 23.2 (CH_2), 10.3 (CH_3). MALDI-TOF MS (925.20): 947.9 (M^+ + Na). Anal. Calcd for $C_{52}H_{68}N_{12}O_4$: C, 67.51; H, 7.41; N, 18.17. Found: C, 67.17; H, 7.22; N, 17.91.

5,11,17,23-Tetrakis{3-[4-(2,3,4,6-tetra-*O*-benzyl-β-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]propyl}-25,26,27,28-tetrapropoxy-calix[4]arene (5a). The calix[4]arene tetraazide **4** (92 mg, 0.10 mmol) was allowed to react with **1a** (220 mg, 0.40 mmol) in the presence of freshly distilled *N*,*N*-diisopropylethylamine (350 μL, 2.00 mmol) and CuI (19 mg, 0.10 mmol) as described for the preparation of **3a** to give, after column chromatography on silica gel (from 3:1 to 1:1 cyclohexane/AcOEt), **5a** (197 mg, 63%) as a white foam; $[\alpha]_D = -3.8$ (*c* 1.0, $CHCl_3$). ^{1}H NMR (400 MHz): δ 7.41 (s, 4H, 4 H-5 Tr.), 7.34−7.22 (m, 52H, Ar), 7.16−7.10 (m, 20H, Ar), 6.97−6.94 (m, 8H, Ar), 6.43 (s, 8H, Ar calix.), 4.93 and 4.87 (2d, 8H, *J* = 11.3 Hz, 4 PhCH_2), 4.84 and 4.55 (2d, 8H, *J* = 10.8 Hz, 4 PhCH_2), 4.60 and 4.27 (2d, 8H, *J* = 10.8 Hz, 4 PhCH_2), 4.52 and 4.46 (2d, 8H, *J* = 12.4 Hz, 4 PhCH_2), 4.51 (d, 4H, $J_{1,2}$ = 9.2 Hz, 4 H-1), 4.39 and 3.04 (2d, 8H, *J* = 13.0 Hz, 4 ArCH_2Ar), 4.14−4.06 (m, 8H, 4 ArCH$_2$CH$_2$CH_2), 3.95 (dd, 4H, $J_{2,3}$ = 9.4 Hz, 4 H-2), 3.82 (t, 8H, *J* = 7.5 Hz, 4 CH$_3$CH$_2$CH_2O), 3.80 (dd, 4H, $J_{3,4}$ = 8.3 Hz, 4 H-3), 3.74−3.66 (m, 12H), 3.64−3.59 (m, 4H), 2.27 (t, 8H, *J* = 7.2 Hz, 4 ArCH_2CH$_2$CH$_2$), 1.97−1.87 (m, 16H, 4 ArCH$_2$CH_2-CH$_2$, 4 CH$_3$CH_2CH$_2$O), 0.98 (t, 12H, *J* = 7.5 Hz, 4 CH_3CH$_2$CH$_2$O).

^{13}C NMR (75 MHz): δ 154.9 (C), 145.3 (C), 138.6 (C), 138.0 (C), 134.8 (C), 133.2 (C), 128.33 (CH), 128.27 (CH), 128.1 (CH), 127.9 (CH), 127.8 (CH), 127.7 (CH), 127.5 (CH), 123.0 (CH), 86.9 (CH), 81.8 (CH), 79.4 (CH), 78.2 (CH), 76.7 (CH_2), 75.5 (CH_2), 75.0 (CH_2), 74.7 (CH_2), 73.9 (CH), 73.3 (CH_2), 69.2 (CH_2), 49.4 (CH_2), 31.8 (CH_2), 30.9 (CH_2), 23.1 (CH_2), 10.2 (CH_3). MALDI-TOF MS (3119.94): 3143.0 (M^+ + Na), 3158.9 (M^+ + K). Anal. Calcd for $C_{196}H_{212}N_{12}O_{24}$: C, 75.45; H, 6.85; N, 5.39. Found: C, 75.11; H, 6.64; N, 5.19.

5,11,17,23-Tetrakis{3-[4-(2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]propyl}-25,26,27,28-tetrapropoxy-calix[4]-arene (5b). The cycloaddition between tetraazide **4** (46 mg, 0.05 mmol) and alkyne **1b** (71 mg, 0.20 mmol) was carried out as described for the preparation of **5a** to give, after column chromatography on silica gel (AcOEt), **5b** (101 mg, 86%) as a syrup; $[\alpha]_D$ = −24.7 (*c* 1.0, $CHCl_3$). ^{1}H NMR (300 MHz): δ 7.64 (s, 4H, 4 H-5 Tr.), 6.46 (s, 8H, Ar), 5.39 (dd, 4H, $J_{2,3} = J_{3,4}$ = 9.2 Hz, 4 H-3), 5.32 (dd, 4H, $J_{1,2}$ = 9.6 Hz, 4 H-2), 5.20 (dd, 4H, $J_{4,5}$ = 9.8 Hz, 4 H-4), 4.86 (d, 4H, 4 H-1), 4.42 and 3.09 (2d, 8H, *J* = 13.1 Hz, 4 ArCH_2Ar), 4.35 (dd, 4H, $J_{5,6a}$ = 4.6, $J_{6a,6b}$ = 12.5 Hz, 4 H-6a), 4.23 (t, 8H, *J* = 7.3 Hz, 4 $ArCH_2CH_2CH_2$), 4.15 (dd, 4H, $J_{5,6b}$ = 1.8 Hz, 4 H-6b), 3.94 (ddd, 4H, 4 H-5), 3.84 (t, 8H, *J* = 7.5 Hz, 4 $CH_3CH_2CH_2O$), 2.32 (t, 8H, *J* = 7.3 Hz, 4 $ArCH_2CH_2CH_2$), 2.09, 2.08, 2.04, and 1.90 (4s, 48H, 16 Ac), 2.08−1.89 (m, 16H, 4 $CH_3CH_2CH_2O$, 4 $ArCH_2CH_2CH_2$), 1.01 (t, 12H, *J* = 7.4 Hz, 4 $CH_3CH_2CH_2O$). ^{13}C NMR (75 MHz): δ 170.6, 170.1, and 169.5 (CO), 155.0 (C Ar), 143.9 (C-4 Tr.), 134.8 and 133.0 (C Ar), 127.9 (CH Ar), 122.2 (C-5 Tr.), 76.7 ($CH_3CH_2CH_2O$), 76.1 (CH), 73.9 (CH), 73.2 (CH), 71.2 (CH), 68.3 (CH), 62.1 (C-6), 49.7 ($ArCH_2CH_2CH_2$), 31.8 (CH_2), 30.9 (CH_2), 23.1 (CH_2), 20.7 and 20.5 (CH_3CO), 10.2 ($CH_3CH_2CH_2O$). MALDI-TOF MS (2350.54): 2374.7 (M^+ + H + Na), 2389.8 (M^+ + K). Anal. Calcd for $C_{116}H_{148}N_{12}O_{40}$: C, 59.27; H, 6.35; N, 7.15. Found: C, 59.01; H, 6.21; N, 6.93.

5,11,17,23-Tetrakis{3-[4-(*β*-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]propyl}-25,26,27,28-tetrapropoxy-calix[4]arene (5c). A solution of **5b** (47 mg, 0.02 mmol) in a 0.2 M solution of NaOMe in MeOH (4 mL, prepared from Na and MeOH immediately before the use) was stirred at room temperature for 4 h in a nitrogen atmosphere (after a few minutes the solution turned turbid), then diluted with H_2O (ca. 0.2 mL), neutralized with Amberlite IR-120 resin (H^+ form, activated and washed with H_2O and MeOH immediately before the use), and filtered through a sintered glass filter. The resin was washed with MeOH, H_2O, and DMF, the solution was concentrated and dried under high vacuum to give **5c** (30 mg, 90%) as an amorphous solid; $[\alpha]_D$ = +7.5 (*c* 0.8, DMF). ^{1}H NMR (400 MHz, CD_3OD): δ 7.97 (bs, 4H, 4 H-5 Tr.), 6.56 (s, 8H, Ar), 4.42 and 3.09 (2d, 8H, *J* = 13.0 Hz, 4 ArCH_2Ar), 4.41−4.37 (m, 4H, 4 H-1), 4.17 (t, 8H, *J* = 6.8 Hz, 4 $ArCH_2CH_2CH_2$), 3.87−3.84 (m, 4H, 4 H-6a), 3.82 (t, 8H, *J* = 7.5 Hz, 4 $CH_3CH_2CH_2O$), 3.69−3.65 (m, 4H, 4 H-6b), 3.62−3.40 (m, 16H), 2.24 (t, 8H, *J* = 7.0 Hz, 4 $ArCH_2CH_2CH_2$), 2.02−1.92 (m, 16H, 4 $CH_3CH_2CH_2O$, 4 $ArCH_2CH_2CH_2$),1.02 (t, 12H, *J* = 7.5 Hz, 4 $CH_3CH_2CH_2O$). ^{13}C NMR (75 MHz, CD_3OD): δ 156.1 (C), 136.1 (C), 135.1 (C), 129.5 (CH), 125.0 (CH), 82.2 (CH), 79.6 (CH), 78.0 (CH_2), 75.6 (CH), 75.0 (CH), 71.6 (CH), 63.0 (CH_2), 50.6 (CH_2), 33.0 (CH_2), 32.8 (CH_2), 31.8 (CH_2), 24.5 (CH_2), 10.9 (CH_3). MALDI-TOF MS (1677.94): 1679.2 (M^+ + H), 1701.3 (M^+ + Na), 1717.2 (M^+ + K). Anal. Calcd for $C_{84}H_{116}N_{12}O_{24}$: C, 60.13; H, 6.97; N, 10.02. Found: C, 59.80; H, 6.72; N, 9.78.

1,3,5-Tris{[4-(2,3,4,6-tetra-*O*-benzyl-*β*-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]methyl}-benzene (7a). Tris(azidomethyl)benzene **6** (12 mg, 0.05 mmol) was allowed to react with **1a** (82 mg, 0.15 mmol) in the presence of freshly distilled *N*,*N*-diisopropylethylamine (130 μL, 0.75 mmol) and CuI (7 mg, 0.037 mmol) as described for the preparation of **3a** to give, after column chromatography on silica gel (2:1 AcOEt/cyclohexane), **7a** (61 mg, 65%) as a white solid. Mp 198−200 °C (toluene); $[\alpha]_D$ = −6.7 (*c* 0.8, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.31−7.22, 7.18−7.10, and 6.98−6.92 (3m, 66H, 12 Ph, C_6H_3, 3 H-5 Tr.), 5.17 and 5.12 (2d, 6H, *J* = 14.5 Hz, 3 CH_2N), 4.92 and 4.89 (2d, 6H, *J* = 11.0 Hz, 3 PhCH_2), 4.84 and 4.55 (2d, 6H, *J* = 10.8 Hz, 3 PhCH_2), 4.64 and 4.26 (2d, 6H, *J* = 11.0 Hz, 3 PhCH_2), 4.53 and 4.48 (2d, 6H, *J* = 12.1 Hz, 3 PhCH_2), 4.50 (d, 3H, $J_{1,2}$ = 9.6 Hz, 3 H-1), 3.92 (dd, 3H, $J_{2,3}$ = 9.0 Hz, 3 H-2), 3.81 (dd, 3H, $J_{3,4}$ = 8.8 Hz, 3 H-3), 3.72 (dd, 3H, $J_{5,6a}$ = 1.6, $J_{6a,6b}$ = 10.8 Hz, 3 H-6a), 3.69 (dd, 3H, $J_{4,5}$ = 9.6 Hz, 3 H-4), 3.67 (dd, 3H, $J_{5,6b}$ = 4.5 Hz, 3 H-6b), 3.62 (ddd, 3H, 3 H-5). ^{1}H NMR (400 MHz, C_6D_6) selected data: δ 7.35−6.95 (m, 60H, 12 Ph), 6.67 and 6.46 (2s, 6H, C_6H_3, 3 H-5 Tr.). ^{13}C NMR (75 MHz): δ 146.2 (C), 138.5 (C), 138.04 (C), 137.96 (C), 136.9 (C), 128.4 (CH), 128.3 (CH), 128.2 (CH), 127.9 (CH), 127.8 (CH), 127.7 (CH), 127.6 (CH), 127.0 (CH), 123.2 (CH), 86.9 (CH), 81.7 (CH), 79.4 (CH), 78.2 (CH), 75.6 (CH_2), 75.1 (CH_2), 74.7 (CH_2), 73.8 (CH), 73.4 (CH_2), 69.1 (CH_2), 52.9 (CH_2). MALDI-TOF MS (1889.29): 1911.9 (M^+ + Na), 1927.7 (M^+ + K). Anal. Calcd for $C_{117}H_{117}N_9O_{15}$: C, 74.38; H, 6.24; N, 6.67. Found: C, 74.60; H, 6.33; N, 6.70.

1,3,5-Tris{[4-(2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]methyl}-benzene (7b). Route *a*. The cycloaddition between triazide **6** (24 mg, 0.10 mmol) and alkyne **1b** (107 mg, 0.30 mmol) was carried out as described for the preparation of **7a** to give, after column chromatography on silica gel (AcOEt then acetone), **7b** (113 mg, 86%) as a syrup; $[\alpha]_D$ = −23.8 (*c* 1.1, $CHCl_3$). ^{1}H NMR (300 MHz): δ 7.69 (s, 3H, 3 H-5 Tr.), 6.94 (s, 3H, C_6H_3), 5.62 and 5.46 (2d, 6H, *J* = 15.5 Hz, 3 CH_2N), 5.39 (dd, 3H, $J_{2,3}$ = 9.6, $J_{3,4}$ = 9.2 Hz, 3 H-3), 5.22 (dd, 3H, $J_{1,2}$ = 9.9 Hz, 3 H-2), 5.17 (dd, 3H, $J_{4,5}$ = 10.1 Hz, 3 H-4), 4.78 (d, 3H, 3 H-1), 4.30 (dd, 3H, $J_{5,6a}$ = 5.1, $J_{6a,6b}$ = 12.6 Hz, 3 H-6a), 4.14 (dd, 3H, $J_{5,6b}$ = 2.2 Hz, 3 H-6b), 3.89 (ddd, 3H, 3 H-5), 2.08, 2.07, 2.04, and 1.94 (4s, 36H, 12 Ac). ^{13}C NMR (75 MHz): δ 170.5, 170.1, 169.7, and 169.5 (CO), 145.0 (C-4 Tr.), 136.8 (C Ar), 126.4 (CH Ar), 122.7 (C-5 Tr.), 76.3 (C-5), 73.5 (C-3), 73.4 (C-1), 71.7 (C-2), 68.3 (C-4), 62.1 (C-6), 53.1 (CH_2N), 20.7, 20.6, and 20.5 (CH_3CO). MALDI-TOF MS (1312.24): 1313.9 (M^+ + H), 1336.0 (M^+ + Na), 1351.9 (M^+ + K). Anal. Calcd for $C_{57}H_{69}N_9O_{27}$: C, 52.17; H, 5.30; N, 9.61. Found: C, 52.25; H, 5.39; N, 9.80.

Route *b*. To a cooled (−60 °C), stirred solution of **7a** (38 mg, 0.02 mmol) in anhydrous CH_2Cl_2 (2 mL) was added dropwise a 1 M solution of BCl_3 in CH_2Cl_2 (480 μL, 0.48 mmol). The solution was stirred at −60 °C for 1 h and, after additional stirring at 0 °C for 1 h, diluted with MeOH (0.5 mL), stirred at 0 °C for 10 min, diluted with triethylamine (0.5 mL), concentrated, and dried under high vacuum to give a white solid. A suspension of the residue and 4-*N*,*N*-(dimethylamino)pyridine (5 mg) in DMF (2 mL), acetic anhydride (2 mL), and triethylamine (2 mL) was stirred at room temperature for 18 h, then concentrated, diluted with CH_2Cl_2 (40 mL), washed with H_2O (2 × 5 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel (3:1 AcOEt/cyclohexane, then acetone) to give **7b** (24 mg, 92%) identical to the compound prepared by route *a*.

1,3,5-Tris{[4-(*β*-D-glucopyranosyl)-1*H*-1,2,3-triazol-1-yl]-methyl}-benzene (7c). The *C*-glycocluster **7b** (26 mg, 0.02 mmol) was deacetylated as described for the preparation of **5c** to give, after a similar workup, **7c** (11 mg, 68%) as an amorphous solid; $[\alpha]_D$ = +3.8 (*c* 0.5, DMF). ^{1}H NMR (400 MHz, CD_3OD): δ 8.06 (s, 3H, 3 H-5 Tr.), 7.31 (s, 3H, C_6H_3), 5.63 (s, 6H, 3 CH_2N), 4.42 (d, 3H, $J_{1,2}$ = 9.0 Hz, 3 H-1), 3.87 (dd, 3H, $J_{5,6a}$ = 2.0, $J_{6a,6b}$ = 12.0 Hz, 3 H-6a), 3.67 (dd, 3H, $J_{5,6b}$ = 5.5 Hz, 3 H-6b), 3.51 (dd, 3H, $J_{2,3}$ = 9.2 Hz, 3 H-2), 3.47 (dd, 3H, $J_{3,4}$ = 8.6 Hz, 3 H-3), 3.44 (ddd, 3H, $J_{4,5}$ = 9.5 Hz, 3 H-5), 3.38 (dd, 3H, 3 H-4). ^{13}C NMR (75 MHz, D_2O): δ 136.7 (C), 127.7 (CH), 125.5 (CH), 80.3 (CH), 77.3 (CH), 73.6 (CH), 73.0 (CH), 69.7 (CH), 61.0 (CH_2), 53.5 (CH_2). MALDI-TOF MS (807.79): 831.0 (M^+ + Na), 847.0 (M^+ + K). Anal. Calcd for $C_{33}H_{45}N_9O_{15}\cdot H_2O$: C, 48.00; H, 5.74; N, 15.26. Found: C, 48.31; H, 5.89; N, 15.10.

2,6-Anhydro-1-azido-3,4,5,7-tetra-*O*-benzyl-1-deoxy-D-*glycero*-D-*gulo*-heptitol (8a). A mixture of known[32] 2,6-anhydro-3,4,5,7-

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tetra-*O*-benzyl-D-*glycero*-D-*gulo*-heptitol (555 mg, 1.00 mmol), prepared by reduction with $NaBH_4$ of the corresponding formyl β-D-*C*-glucopyranoside,[33] diphenyl phosphoryl azide (650 μL, 3.00 mmol), 1,8-diazabicyclo[5.4.0.]undec-7-ene (150 μL, 1.00 mmol), and anhydrous DMF (5 mL) was stirred at 100 °C for 2 h then cooled to room temperature. Sodium azide (195 mg, 3.00 mmol) was added in one portion, and then the reaction mixture was stirred at 100 °C for an additional 14 h, cooled to room temperature, diluted with Et_2O (200 mL), washed with H_2O (2 × 20 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel with 8:1 cyclohexane/AcOEt to give **8a** (440 mg, 76%) as a syrup; $[\alpha]_D = -27.9$ (*c* 1.3, $CHCl_3$). ^{1}H NMR (400 MHz, C_6D_6): δ 7.34−7.01 (m, 20H, Ar), 4.84 and 4.77 (2d, 2H, J = 11.2 Hz, PhCH_2), 4.81 and 4.60 (2d, 2H, J = 11.2 Hz, PhCH_2), 4.76 and 4.40 (2d, 2H, J = 11.4 Hz, PhCH_2), 4.49 and 4.39 (2d, 2H, J = 12.1 Hz, PhCH_2), 3.70 (dd, 1H, $J_{4,5}$ = 8.8, $J_{5,6}$ = 9.8 Hz, H-5), 3.65 (dd, 1H, $J_{6,7a}$ = 3.7, $J_{7a,7b}$ = 11.1 Hz, H-7a), 3.61 (dd, 1H, $J_{6,7b}$ = 2.0 Hz, H-7b), 3.54 (dd, 1H, $J_{3,4}$ = 9.1 Hz, H-4), 3.38 (dd, 1H, $J_{2,3}$ = 9.4 Hz, H-3), 3.23 (ddd, 1H, H-6), 3.16 (ddd, 1H, $J_{1a,2}$ = 2.4, $J_{1b,2}$ = 5.5 Hz, H-2), 3.11 (dd, 1H, $J_{1a,1b}$ = 13.0 Hz, H-1a), 2.92 (dd, 1H, H-1b). ^{13}C NMR (75 MHz): δ 138.4 (C), 138.2 (C), 138.0 (C), 137.8 (C), 128.51 (CH), 128.45 (CH), 128.37 (CH), 127.9 (CH), 127.8 (CH), 127.7 (CH), 127.6 (CH), 87.0 (CH), 79.2 (CH), 78.7 (CH), 78.4 (CH), 78.3 (CH), 75.6 (CH_2), 75.2 (CH_2), 75.1 (CH_2), 73.6 (CH_2), 69.0 (CH_2), 51.3 (CH_2). Anal. Calcd for $C_{35}H_{37}N_3O_5$: C, 72.52; H, 6.43; N, 7.25. Found: C, 72.70; H, 6.56; N, 7.43.

3,4,5,7-Tetra-*O*-acetyl-2,6-anhydro-1-azido-1-deoxy-D-*glycero*-D-*gulo*-heptitol (8b). To a cooled (−60 °C), stirred solution of **8a** (232 mg, 0.40 mmol) in anhydrous CH_2Cl_2 (4 mL) was added dropwise a 1 M solution of BCl_3 in CH_2Cl_2 (3.2 mL, 3.20 mmol). The solution was allowed to reach −30 °C in 2 h, then was stirred at 0 °C for 1 h, diluted with MeOH (3 mL), stirred at 0 °C for an additional 10 min, diluted with triethylamine (3 mL), concentrated, and dried under high vacuum to give a white solid. A suspension of the residue in DMF (4 mL), acetic anhydride (4 mL), and triethylamine (4 mL) was stirred at room temperature for 18 h, then concentrated, diluted with AcOEt (100 mL), washed with H_2O (2 × 20 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel with 1:1 cyclohexane/AcOEt to give **8b** (115 mg, 74%) as a white solid. Mp 112−113 °C (AcOEt/cyclohexane); $[\alpha]_D = -7.8$ (*c* 1.0, $CHCl_3$). ^{1}H NMR (300 MHz): δ 5.23 (dd, 1H, $J_{3,4}$ = 9.6, $J_{4,5}$ = 9.1 Hz, H-4), 5.10 (dd, 1H, $J_{5,6}$ = 9.3 Hz, H-5), 5.04 (dd, 1H, $J_{2,3}$ = 9.7 Hz, H-3), 4.25 (dd, 1H, $J_{6,7a}$ = 5.1, $J_{7a,7b}$ = 12.3 Hz, H-7a), 4.16 (dd, 1H, $J_{6,7b}$ = 2.5 Hz, H-7b), 3.74 (ddd, 1H, H-6), 3.70 (ddd, 1H, $J_{1a,2}$ = 6.4, $J_{1b,2}$ = 2.8 Hz, H-2), 3.36 (dd, 1H, $J_{1a,1b}$ = 13.4 Hz, H-1a), 3.28 (dd, 1H, H-1b), 2.10, 2.06, 2.05, and 2.03 (4s, 12H, 4 Ac). ^{13}C NMR (75 MHz): δ 170.6, 170.3, 169.4, and 169.3 (CO), 77.3 (C-2), 75.7 (C-6), 73.9 (C-4), 69.3 (C-3), 68.3 (C-5), 62.1 (C-7), 50.9 (C-1), 20.6 and 20.5 (CH_3CO). Anal. Calcd for $C_{15}H_{21}N_3O_9$: C, 46.51; H, 5.46; N, 10.85. Found: C, 46.60; H, 5.51; N, 10.96.

1,3,5-Tris[1-(2,6-anhydro-3,4,5,7-tetra-*O*-benzyl-1-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-benzene (10a). A mixture of triethynylbenzene **9** (7.5 mg, 0.05 mmol), sugar azide **8a** (130 mg, 0.225 mmol), freshly distilled *N*,*N*-diisopropylethylamine (195 μL, 1.125 mmol), CuI (7 mg, 0.037 mmol), and anhydrous toluene (1 mL) was sonicated in an ultrasound cleaning bath for 1 min, then magnetically stirred in the dark at 80 °C for 48 h, cooled to room temperature, diluted with AcOEt (100 mL), washed with 1 M phosphate buffer at pH 7 (2 × 10 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel (from 4:1 to 1:1 cyclohexane/AcOEt) to give first unchanged **8a** (58 mg, 45%). Eluted second was **10a** (64 mg, 68%) as a syrup; $[\alpha]_D = -40.1$ (*c* 0.7, $CHCl_3$). ^{1}H NMR (400 MHz): δ 8.37 and 8.12 (2s, 6H, C_6H_3, 3 H-5 Tr.), 7.40−7.07 (m, 60H, 12 Ph), 4.93 and 4.89 (2d, 6H, J = 11.1 Hz, 3 PhCH_2), 4.86 and 4.77 (2d, 6H, J = 10.8 Hz, 3 PhCH_2), 4.74 and 4.48 (2d, 6H, J = 10.8 Hz, 3 PhCH_2), 4.67 (d, 6H, $J_{1,2}$ = 4.0 Hz, 6 H-1), 4.63 and 4.54 (2d, 6H, J = 12.2 Hz, 3 PhCH_2), 3.74 (dd, 3H, $J_{3,4}$ = 9.2, $J_{4,5}$ = 8.6 Hz, 3 H-4), 3.72−3.65 (m, 9H, 3 H-2, 6 H-7), 3.53 (dd, 3H, $J_{5,6}$ = 9.8 Hz, 3 H-5), 3.47 (ddd, 3H, $J_{6,7a}$ = 3.8, $J_{6,7b}$ = 2.3 Hz, 3 H-6), 3.22 (dd, 3H, $J_{2,3}$ = 9.5 Hz, 3 H-3). ^{13}C NMR (75 MHz): δ 147.2 (C-4 Tr.), 138.3 and 137.8 (C Bn), 132.0 (C Ph), 128.5−127.5 (CH Bn), 122.4 and 122.1 (CH Ph, C-5 Tr.), 87.0 (CH), 79.0 (CH), 78.1 (CH), 78.0 (CH), 77.1 (CH), 75.5, 75.1, and 73.5 (PhCH_2), 68.7 (C-7), 50.8 (C-1). MALDI-TOF MS (1889.29): 1890.0 (M^+ + H), 1911.9 (M^+ + Na). Anal. Calcd for $C_{117}H_{117}N_9O_{15}$: C, 74.38; H, 6.24; N, 6.67. Found: C, 74.51; H, 6.40; N, 6.85.

1,3,5-Tris[1-(3,4,5,7-tetra-*O*-acetyl-2,6-anhydro-1-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-benzene (10b). Route *a*. The cycloaddition between triethynylbenzene **9** (7.5 mg, 0.05 mmol) and sugar azide **8b** (87 mg, 0.225 mmol) was carried out as described for the preparation of **10a** except for the reaction time (18 h instead of 48 h). The residue was eluted from a column of silica gel (4:1 AcOEt/cyclohexane, then AcOEt) to give first unchanged **8b** (26 mg, 30%). Eluted second was **10b** (63 mg, 96%) as a syrup; $[\alpha]_D = +23.1$ (*c* 0.8, $CHCl_3$). ^{1}H NMR (300 MHz): δ 8.36 and 8.14 (2s, 6H, C_6H_3, 3 H-5 Tr.), 5.28 (dd, 3H, $J_{3,4}$ = 9.6, $J_{4,5}$ = 9.2 Hz, 3 H-4), 5.10 (dd, 3H, $J_{5,6}$ = 10.2 Hz, 3 H-5), 4.96 (dd, 3H, $J_{2,3}$ = 9.8 Hz, 3 H-3), 4.72 (dd, 3H, $J_{1a,2}$ = 2.2, $J_{1a,1b}$ = 14.5 Hz, 3 H-1a), 4.44 (dd, 3H, $J_{1b,2}$ = 8.4 Hz, 3 H-1b), 4.27 (dd, 3H, $J_{6,7a}$ = 5.3, $J_{7a,7b}$ = 12.3 Hz, 3 H-7a), 4.16 (dd, 3H, $J_{6,7b}$ = 2.1 Hz, 3 H-7b), 3.94 (ddd, 3H, 3 H-2), 3.70 (ddd, 3H, 3 H-6), 2.16, 2.05, 2.04, and 2.00 (4s, 36H, 12 Ac). ^{13}C NMR (75 MHz): δ 170.6, 170.1, 169.7, and 169.3 (CO), 147.1 (C-4 Tr.), 131.6 (C Ar), 122.3 and 122.1 (CH Ar, C-5 Tr.), 76.3 (CH), 75.9 (CH), 73.7 (CH), 69.6 (CH), 68.1 (CH), 61.8 (C-7), 51.1 (C-1), 20.6 and 20.5 (CH_3CO). MALDI-TOF MS (1312.24): 1313.6 (M^+ + H), 1335.6 (M^+ + Na), 1351.6 (M^+ + K). Anal. Calcd for $C_{57}H_{69}N_9O_{27}$: C, 52.17; H, 5.30; N, 9.61. Found: C, 52.33; H, 5.41; N, 9.78.

Route *b*. The *C*-glycocluster **10a** (38 mg, 0.02 mmol) was debenzylated and acetylated as described for the preparation of **7b** to give, after column chromatography on silica gel (AcOEt), **10b** (23 mg, 88%) identical to the compound prepared by route *a*.

1,3,5-Tris[1-(2,6-anhydro-1-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-benzene (10c). The *C*-glycocluster **10b** (26 mg, 0.02 mmol) was deacetylated as described for the preparation of **5c** to give, after a similar workup, **10c** (14.5 mg, 90%) as an amorphous solid; $[\alpha]_D = +10.5$ (*c* 0.9, DMF). ^{1}H NMR (400 MHz, DMSO-d_6 + D_2O): δ 8.62 and 8.26 (2s, 6H, C_6H_3, 3 H-5 Tr.), 4.78 (dd, 3H, $J_{1a,2}$ = 1.8, $J_{1a,1b}$ = 14.5 Hz, 3 H-1a), 4.43 (dd, 3H, $J_{1b,2}$ = 8.0 Hz, 3 H-1b), 3.62 (dd, 3H, $J_{6,7a}$ = 1.5, $J_{7a,7b}$ = 12.0 Hz, 3 H-7a), 3.47 (ddd, 3H, $J_{2,3}$ = 9.5 Hz, 3 H-2), 3.40 (dd, 6H, $J_{6,7b}$ = 6.0 Hz, 3 H-7b), 3.18 (dd, 3H, $J_{3,4}$ = 8.8, $J_{4,5}$ = 8.5 Hz, 3 H-4), 3.08 (ddd, 3H, $J_{5,6}$ = 9.5 Hz, 3 H-6), 3.01 (dd, 3H, 3 H-5), 2.95 (dd, 3H, 3 H-3). ^{13}C NMR (75 MHz, DMSO-d_6): δ 146.2 (C), 132.4 (C), 123.4 (CH), 121.7 (CH), 80.7 (CH), 78.1 (CH), 77.9 (CH), 71.4 (CH), 70.3 (CH), 61.4 (CH_2), 51.8 (CH_2). MALDI-TOF MS (807.79): 809.3 (M^+ + H), 831.3 (M^+ + Na), 847.3 (M^+ + K). Anal. Calcd for $C_{33}H_{45}N_9O_{15}$: C, 49.07; H, 5.61; N, 15.61. Found: C, 48.70; H, 5.60; N, 15.42.

3,4,5,7-Tetra-*O*-acetyl-2,6-anhydro-1-azido-1-deoxy-D-*glycero*-L-*manno*-heptitol (11b). Known[19] benzylated azidomethyl *C*-galactoside **11a** (464 mg, 0.80 mmol) was treated as described for the preparation of **8b** to give, after column chromatography on silica gel (1.5:1 cyclohexane/AcOEt), **11b** (217 mg, 70%) as a syrup; $[\alpha]_D = +14.6$ (*c* 0.7, $CHCl_3$). ^{1}H NMR (300 MHz): δ 5.46 (dd, 1H, $J_{4,5}$ = 3.3, $J_{5,6}$ = 1.3 Hz, H-5), 5.22 (dd, 1H, $J_{2,3}$ = 9.5, $J_{3,4}$ = 10.1 Hz, H-3), 5.07 (dd, 1H, H-4), 4.19 (dd, 1H, $J_{6,7a}$ = 7.0, $J_{7a,7b}$ = 11.3 Hz, H-7a), 4.10 (dd, 1H, $J_{6,7b}$ = 6.2 Hz, H-7b), 3.97 (ddd, 1H, H-6), 3.68 (ddd, 1H, $J_{1a,2}$ = 7.1, $J_{1b,2}$ = 2.5 Hz, H-2), 3.41 (dd, 1H, $J_{1a,1b}$ = 13.4 Hz, H-1a), 3.23 (dd, 1H, H-1b), 2.19 (s, 3H, Ac), 2.08 (s, 6H, 2 Ac), 2.01 (s, 3H, Ac). ^{13}C NMR (75 MHz): δ 170.4, 170.2, 170.0, and 169.7 (CO), 77.9 (C-2), 74.2 (C-6), 71.8 (C-4), 67.4 (C-5), 66.9 (C-3), 61.6 (C-7), 51.0 (C-1), 20.6 and 20.5

(33) Dondoni, A.; Marra, A. *Tetrahedron Lett.* **2003**, *44*, 13.

(CH_3CO). Anal. Calcd for $C_{15}H_{21}N_3O_9$: C, 46.51; H, 5.46; N, 10.85. Found: C, 46.80; H, 5.58; N, 10.98.

1,3,5-Tris[1-(2,6-anhydro-3,4,5,7-tetra-*O*-benzyl-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-benzene (12a). The cycloaddition between triethynylbenzene **9** (7.5 mg, 0.05 mmol) and sugar azide **11a** (130 mg, 0.225 mmol) was carried out as described for the preparation of **10a** to give, after column chromatography on silica gel (from 3:1 to 1:1 cyclohexane/AcOEt), first unchanged **8a** (75 mg, 50%). Eluted second was **12a** (58 mg, 62%) as a syrup; $[\alpha]_D = -31.6$ (*c* 0.8, $CHCl_3$). ^{1}H NMR (400 MHz): δ 8.30 and 8.12 (2s, 6H, C_6H_3, 3 H-5 Tr.), 7.40−7.07 (m, 60H, 12 Ph), 4.94 and 4.73 (2d, 6H, $J = 10.7$ Hz, 3 PhCH_2), 4.86 and 4.52 (2d, 6H, $J = 11.8$ Hz, 3 PhCH_2), 4.75 and 4.66 (2d, 6H, $J = 11.8$ Hz, 3 PhCH_2), 4.73 (dd, 3H, $J_{1a,2} = 1.0$, $J_{1a,1b} = 14.5$ Hz, 3 H-1a), 4.59 (dd, 3H, $J_{1b,2} = 5.0$ Hz, 3 H-1b), 4.45 and 4.38 (2d, 6H, $J = 11.8$ Hz, 3 PhCH_2), 3.98−3.97 (m, 3H, 3 H-5), 3.69−3.64 (m, 9H), 3.59−3.53 (m, 9H).). ^{13}C NMR (75 MHz): δ 147.1 (C-4 Tr.), 138.3, 138.0, 137.9, and 137.7 (C Bn), 131.9 (C Ph), 128.4−127.4 (CH Bn), 122.4 and 122.0 (CH Ph, C-5 Tr.), 84.5 (CH), 77.7 (CH), 77.1 (CH), 75.2, 74.4, 73.5, and 72.0 (PhCH_2), 75.0 (CH), 73.2 (CH), 68.7 (C-7), 51.3 (C-1). MALDI-TOF MS (1889.29): 1890.1 ($M^+ + H$), 1912.0 ($M^+ + Na$), 1927.9 ($M^+ + K$). Anal. Calcd for $C_{117}H_{117}N_9O_{15}$: C, 74.38; H, 6.24; N, 6.67. Found: C, 74.66; H, 6.38; N, 6.75.

1,3,5-Tris[1-(3,4,5,7-tetra-*O*-acetyl-2,6-anhydro-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-benzene (12b). Route *a*. The cycloaddition between triethynylbenzene **9** (7.5 mg, 0.05 mmol) and sugar azide **11b** (87 mg, 0.225 mmol) was carried out as described for the preparation of **10b** to give, after column chromatography on silica gel (4:1 AcOEt/cyclohexane, then AcOEt), first unchanged **11b** (31 mg, 36%). Eluted second was **12b** (54 mg, 82%) as a syrup; $[\alpha]_D = +59.5$ (*c* 1.1, $CHCl_3$). ^{1}H NMR (300 MHz): δ 8.38 and 8.15 (2s, 6H, C_6H_3, 3 H-5 Tr.), 5.48 (dd, 3H, $J_{4,5} = 3.3$, $J_{5,6} = 0.8$ Hz, 3 H-5), 5.21 (dd, 3H, $J_{2,3} = 9.6$, $J_{3,4} = 10.1$ Hz, 3 H-3), 5.10 (dd, 3H, 3 H-4), 4.74 (dd, 3H, $J_{1a,2} = 2.3$, $J_{1a,1b} = 14.4$ Hz, 3 H-1a), 4.46 (dd, 3H, $J_{1b,2} = 9.0$ Hz, 3 H-1b), 4.24 (dd, 3H, $J_{6,7a} = 7.4$, $J_{7a,7b} = 11.6$ Hz, 3 H-7a), 4.08 (dd, 3H, $J_{6,7b} = 5.2$ Hz, 3 H-7b), 3.91 (ddd, 3H, 3 H-2), 3.89 (ddd, 3H, 3 H-6), 2.20, 2.18, 2.02, and 1.90 (4s, 36H, 12 Ac). ^{13}C NMR (75 MHz): δ 170.4, 170.1, and 169.9 (CO), 147.0 (C-4 Tr.), 131.8 (C Ar), 122.3 and 122.0 (CH Ar, C-5 Tr.), 76.8 (CH), 74.7 (CH), 71.6 (CH), 67.5 (CH), 67.1 (CH), 61.6 (C-7), 51.4 (C-1), 20.8, 20.6, and 20.5 (CH_3CO). MALDI-TOF MS (1312.24): 1314.0 ($M^+ + H$), 1336.1 ($M^+ + Na$), 1352.0 ($M^+ + K$). Anal. Calcd for $C_{57}H_{69}N_9O_{27}$: C, 52.17; H, 5.30; N, 9.61. Found: C, 52.30; H, 5.37; N, 9.89.

Route *b*. The *C*-glycocluster **12a** (38 mg, 0.02 mmol) was debenzylated and acetylated as described for the preparation of **7b** to give, after column chromatography on silica gel (AcOEt), **12b** (22 mg, 84%) identical to the compound prepared by route *a*.

1,3,5-Tris[1-(2,6-anhydro-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-benzene (12c). The *C*-glycocluster **12b** (26 mg, 0.02 mmol) was deacetylated as described for the preparation of **5c** to give, after a similar workup, **12c** (14 mg, 88%) as an amorphous solid; $[\alpha]_D = +15.8$ (*c* 0.4, DMF). ^{1}H NMR (300 MHz, D_2O): δ 7.80 and 7.02 (2s, 6H, C_6H_3, 3 H-5 Tr.), 4.56 (dd, 3H, $J_{1a,2} = 1.0$, $J_{1a,1b} = 14.5$ Hz, 3 H-1a), 4.21 (dd, 3H, $J_{1b,2} = 7.5$ Hz, 3 H-1b), 3.84 (dd, 3H, $J_{4,5} = 3.0$, $J_{5,6} = 0.5$ Hz, 3 H-5), 3.67 (dd, 3H, $J_{6,7a} = 9.0$, $J_{7a,7b} = 12.0$ Hz, 3 H-7a), 3.61−3.37 (m, 15 H). ^{13}C NMR (75 MHz, D_2O): δ 146.0 (C), 130.2 (C), 122.8 (CH), 121.0 (CH), 78.7 (CH), 78.1 (CH), 74.2 (CH), 69.3 (CH), 68.6 (CH), 61.5 (CH_2), 51.7 (CH_2). MALDI-TOF MS (807.79): 831.1 ($M^+ + Na$), 847.1 ($M^+ + K$). Anal. Calcd for $C_{33}H_{45}N_9O_{15}\cdot H_2O$: C, 48.00; H, 5.74; N, 15.26. Found: C, 48.22; H, 5.83; N, 15.38.

5,11,17,23-Tetraethynyl-25,26,27,28-tetrapropoxy-calix[4]-arene (13). To an oxygen-free solution, obtained by bubbling argon at room temperature for 10 min, of known[21] 5,11,17,23-tetraiodo-25,26,27,28-tetrapropoxy-calix[4]arene (329 mg, 0.30 mmol) in anhydrous toluene (1 mL) and freshly distilled triethylamine (9 mL) were added commercially available (trimethylsilyl)acetylene (210 μL, 1.50 mmol), $PdCl_2(PPh_3)_2$ (21 mg, 0.03 mmol) and CuI (3 mg, 0.015 mmol). The mixture was stirred in a screw-capped vial at 50 °C for 24 h in the dark, then cooled to room temperature, partially concentrated, diluted with 1 M aqueous HCl (ca. 30 mL), and extracted with AcOEt (150 mL). The organic phase was washed with H_2O (2 × 20 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a short column of silica gel with 9:1 cyclohexane/AcOEt to give 25,26,27,28-tetrapropoxy-5,11,17,23-tetrakis(trimethylsilylethynyl)-calix[4]arene contaminated by small amounts of uncharacterized byproducts as a light brown foam (0.30 g). A mixture of the latter compound, KF (0.87 g, 15.0 mmol), and DMF (30 mL) was stirred at 60 °C for 4 h, partially concentrated under vacuum, diluted with 0.01 M aqueous HCl (50 mL), and extracted with AcOEt (2 × 100 mL). The organic phase was washed with H_2O (2 × 20 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel with 10:1 cyclohexane/AcOEt to give **13** (74 mg, 36%) as an amorphous solid. ^{1}H NMR (300 MHz): δ 6.85 (s, 8H, Ar), 4.39 and 3.13 (2 d, 8H, $J = 13.5$ Hz, 4 ArCH_2Ar), 3.89−3.83 (m, 8H, 4 $CH_3CH_2CH_2O$), 2.91 (s, 4H, 4 C≡CH), 1.97−1.84 (m, 8H, 4 $CH_3CH_2CH_2O$), 1.00 (t, 12H, $J = 7.5$ Hz, 4 $CH_3CH_2CH_2O$). ^{13}C NMR (75 MHz): δ 157.1 (C Ar), 134.7 (C Ar), 132.2 (CH Ar), 115.9 (C Ar), 83.9 (C≡*C*H), 76.9 ($CH_3CH_2CH_2O$), 75.8 (*C*≡CH), 30.6 (ArCH_2Ar), 23.1 ($CH_3CH_2CH_2O$), 10.2 ($CH_3CH_2CH_2O$). MALDI-TOF MS (688.91): 690.0 ($M^+ + H$), 712.0 ($M^+ + Na$), 728.0 ($M^+ + K$). Anal. Calcd for $C_{48}H_{48}O_4$: C, 83.69; H, 7.02; N. Found: C, 83.32; H, 6.70.

5,11,17,23-Tetrakis[1-(2,6-anhydro-3,4,5,7-tetra-*O*-benzyl-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-25,26,27,28-tetrapropoxy-calix[4]arene (14a). The cycloaddition between tetraethynyl-calix[4]arene **13** (34.5 mg, 0.05 mmol) and sugar azide **11a** (174 mg, 0.30 mmol) was carried out at 80 °C for 18 h as described for the preparation of **10b** to give, after column chromatography on silica gel (from 5:1 to 2:1 cyclohexane/AcOEt), first unchanged **11a** (83 mg, 48%). Eluted second was **14a** (92 mg, 61%) as an amorphous solid; $[\alpha]_D = -76.2$ (*c* 1.1, $CHCl_3$). ^{1}H NMR (400 MHz, C_6D_6): δ 7.97 and 7.63 (2s, 8H, Ar, 4 H-5 Tr.), 7.38−7.32 (m, 8H, Ar), 7.23−7.00 (m, 76H, Ar), 4.84 and 4.52 (2d, 8H, $J = 11.9$ Hz, 4 PhCH_2), 4.78 and 4.70 (2d, 8H, $J = 11.2$ Hz, 4 PhCH_2), 4.58 and 4.46 (2d, 8H, $J = 11.5$ Hz, 4 PhCH_2), 4.55 and 3.16 (2d, 8H, $J = 13.5$ Hz, 4 ArCH_2Ar), 4.42 (dd, 4H, $J_{1a,2} = 4.8$, $J_{1a,1b} = 13.5$ Hz, 4 H-1a), 4.31 (dd, 4H, $J_{1b,2} = 1.5$ Hz, 4 H-1b), 4.29 and 4.22 (2d, 8H, $J = 12.0$ Hz, 4 PhCH_2), 3.99−3.91 (m, 8H, 4 $CH_3CH_2CH_2O$), 3.78 (dd, 4H, $J_{4,5} = 2.0$, $J_{5,6} = 0.4$ Hz, 4 H-5), 3.68 (dd, 4H, $J_{6,7a} = 7.5$, $J_{7a,7b} = 9.3$ Hz, 4 H-7a), 3.62 (dd, 4H, $J_{6,7b} = 5.6$ Hz, 4 H-7b), 3.58 (dd, 4H, $J_{2,3} = 9.6$, $J_{3,4} = 9.2$ Hz, 4 H-3), 3.38 (ddd, 4H, 4 H-6), 3.31 (dd, 4H, 4 H-4), 3.29 (ddd, 4H, 4 H-2), 2.03−1.90 (m, 8H, 4 $CH_3CH_2CH_2O$), 1.00 (t, 12H, $J = 7.5$ Hz, 4 $CH_3CH_2CH_2O$). ^{13}C NMR (75 MHz): δ 156.6 (C), 147.4 (C), 138.8 (C), 138.2 (C), 138.1 (C),135.2 (C), 128.3 (CH), 128.0 (CH), 127.8 (CH), 127.5 (CH), 127.4 (CH), 127.0 (CH),126.8 (CH), 125.8 (CH), 124.7 (CH), 120.4 (CH), 84.5 (CH), 77.4 (CH), 76.9 (CH), 76.5 (CH_2), 75.0 (CH_2), 74.5 (CH), 74.1 (CH_2), 73.4 (CH_2), 71.8 (CH_2), 68.6 (CH_2), 50.5 (CH_2), 31.2 (CH_2), 23.2 (CH_2), 10.3 (CH_3). MALDI-TOF MS (3007.72): 3009.1 ($M^+ + H$), 3030.8 ($M^+ + Na$), 3046.7 ($M^+ + K$). Anal. Calcd for $C_{188}H_{196}N_{12}O_{24}$: C, 75.07; H, 6.57; N, 5.59. Found: C, 74.72; H, 6.38; N, 5.30.

5,11,17,23-Tetrakis[1-(3,4,5,7-tetra-*O*-acetyl-2,6-anhydro-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-25,26,27,28-tetrapropoxy-calix[4]arene (14b). Route *a*. The cycloaddition between tetraethynyl-calix[4]arene **13** (34.5 mg, 0.05 mmol) and sugar azide **11b** (116 mg, 0.30 mmol) was carried out as described for the preparation of **10b** to give, after column chromatography on silica gel (1:1 AcOEt/cyclohexane, then AcOEt), first unchanged **11b** (49 mg, 42%). Eluted second was **14b** (93 mg, 83%) as a syrup; $[\alpha]_D = +41.2$ (*c* 1.0, $CHCl_3$). ^{1}H NMR (400 MHz): δ 7.44 (s, 4H, 4 H-5 Tr.), 7.22 and 7.02 (2s, 8H, Ar), 5.40

(dd, 4H, $J_{4,5}$ = 3.1, $J_{5,6}$ = 0.8 Hz, 4 H-5), 5.13 (dd, 4H, $J_{2,3}$ = 9.5, $J_{3,4}$ = 10.0 Hz, 4 H-3), 5.07 (dd, 4H, 4 H-4), 4.51 and 3.24 (2d, 8H, J = 13.5 Hz, 4 ArCH_2Ar), 4.49 (dd, 4H, $J_{1a,2}$ = 2.2, $J_{1a,1b}$ = 14.4 Hz, 4 H-1a), 4.25 (dd, 4H, $J_{1b,2}$ = 9.3 Hz, 4 H-1b), 4.05 (dd, 4H, $J_{6,7a}$ = 6.5, $J_{7a,7b}$ = 11.3 Hz, 4 H-7a), 4.02 (dd, 4H, $J_{6,7b}$ = 6.7 Hz, 4 H-7b), 3.89 (t, 8H, J = 7.5 Hz, 4 $CH_3CH_2CH_2O$), 3.82 (ddd, 4H, 4 H-6), 3.78 (ddd, 4H, 4 H-2), 2.18, 2.12, 1.99, and 1.88 (4s, 48H, 16 Ac), 1.93 (tq, 8H, J = 7.5, 7.5 Hz, 4 $CH_3CH_2CH_2O$), 1.00 (t, 12H, J = 7.5 Hz, 4 $CH_3CH_2CH_2O$). ^{13}C NMR (75 MHz): δ 170.3, 170.1, and 169.9 (CO), 156.8 (C Ar), 147.6 (C-4 Tr.), 135.3 (C Ar), 125.7 and 125.4 (CH Ar), 124.2 (C Ar), 120.6 (C-5 Tr), 76.8 ($CH_3CH_2CH_2O$), 76.6 (C-2), 74.3 (C-6), 71.6 (C-4), 67.5 (C-5), 67.3 (C-3), 61.3 (C-7), 51.0 (C-1), 31.1 (ArCH_2Ar), 23.1 ($CH_3CH_2CH_2O$), 20.75, 20.67, and 20.5 (CH_3CO), 10.3 (CH_3CH_2-CH_2O). MALDI-TOF MS (2238.33): 2262.7 (M^+ + H + Na), 2278.6 (M^+ + H + K). Anal. Calcd for $C_{108}H_{132}N_{12}O_{40}$: C, 57.95; H, 5.94; N, 7.51. Found: C, 57.70; H, 5.77; N, 7.28.

Route *b*. The *C*-glycocluster **14a** (60 mg, 0.02 mmol) was debenzylated and acetylated as described for the preparation of **7b** to give, after column chromatography on silica gel (2:1 AcOEt/cyclohexane, then AcOEt), **14b** (41 mg, 91%) identical to the compound prepared by route *a*.

5,11,17,23-Tetrakis[1-(2,6-anhydro-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-25,26,27,28-tetrapropoxycalix[4]arene (14c). The *C*-glycocluster **14b** (22.5 mg, 0.01 mmol) was deacetylated as described for the preparation of **5c** to give, after a similar workup, **14c** (15 mg, 96%) as an amorphous solid; $[\alpha]_D$ = +15.8 (*c* 0.5, DMF). ^{1}H NMR (300 MHz, DMSO-d_6 + D_2O) selected data: δ 7.94 (s, 4H, 4 H-5 Tr.), 7.20 and 7.09 (2d, 8H, J = 1.5 Hz, Ar), 4.66 (dd, 4H, $J_{1a,2}$ = 1.0, $J_{1a,1b}$ = 14.5 Hz, 4 H-1a), 4.42 (d, 4H, J = 13.0 Hz, 4 H_{ax} of ArCH_2Ar), 4.20 (dd, 4H, $J_{1b,2}$ = 5.5 Hz, 4 H-1b), 3.86 (t, 8H, J = 7.5 Hz, 4 $CH_3CH_2CH_2O$), 1.97−1.82 (m, 8H, 4 $CH_3CH_2CH_2O$), 0.99 (t, 12H, J = 7.5 Hz, 4 $CH_3CH_2CH_2O$). ^{13}C NMR (75 MHz, DMSO-d_6): δ 155.9 (C), 146.1 (C), 134.7 (C), 125.2 (CH), 124.8 (CH), 124.7 (C), 121.0 (CH), 78.8 (CH), 78.6 (CH), 76.4 (CH_2), 74.3 (CH), 68.6 (CH), 68.3 (CH), 60.6 (CH_2), 51.2 (CH_2), 30.5 (CH_2), 22.8 (CH_2), 10.2 (CH_3). MALDI-TOF MS (1565.72): 1567.1 (M^+ + H), 1589.2 (M^+ + Na), 1605.1 (M^+ + K). Anal. Calcd for $C_{76}H_{100}N_{12}O_{24}\cdot H_2O$: C, 57.64; H, 6.49; N, 10.61. Found: C, 57.79; H, 6.60; N, 10.80.

1,3,5,7-Tetrakis{4-[1-(2,6-anhydro-3,4,5,7-tetra-*O*-benzyl-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-phenyl}-adamantane (16a). The cycloaddition between tetraethynyl-adamantane **15** (27 mg, 0.05 mmol) and sugar azide **11a** (174 mg, 0.30 mmol) was carried out at 80 °C for 18 h as described for the preparation of **10b** to give, after column chromatography on silica gel (from 3:1 to 1:1 cyclohexane/AcOEt), first unchanged **11a** (80 mg, 46%). Eluted second was **16a** (114 mg, 80%) as an amorphous solid; $[\alpha]_D$ = −32.1 (*c* 1.0, $CHCl_3$). ^{1}H NMR (400 MHz): δ 8.00 (s, 4H, 4 H-5 Tr.), 7.80−7.76 and 7.57−7.53 (2m, 16H, 4 C_6H_4), 7.40−7.09 (m, 80H, 16 Ph), 4.92 and 4.53 (2d, 8H, J = 11.9 Hz, 4 PhCH_2), 4.91 and 4.61 (2d, 8H, J = 10.5 Hz, 4 PhCH_2), 4.76 and 4.69 (2d, 8H, J = 11.5 Hz, 4 PhCH_2), 4.72−4.63 (m, 8H, 8 H-1), 4.47 and 4.43 (2d, 8H, J = 12.0 Hz, 4 PhCH_2), 3.96 (dd, 4H, $J_{4,5}$ = 2.3, $J_{5,6}$ = 0.4 Hz, 4 H-5), 3.70−3.58 (m, 20H), 3.54 (dd, 4H, $J_{6,7b}$ = 9.0, $J_{7a,7b}$ = 11.5 Hz, 4 H-7b), 2.28 (bs, 12H, 6 CH_2). ^{13}C NMR (75 MHz): δ 149.0 (C), 147.4 (C), 138.4 (C), 138.0 (C), 137.9 (C), 137.7 (C), 128.9 (C), 128.4 (CH), 128.2 (CH), 127.9 (CH), 127.7 (CH), 127.5 (CH), 127.4 (CH), 125.8 (CH), 125.4 (CH), 121.3 (CH), 84.4 (CH), 77.6 (CH), 77.1 (CH), 75.3 (CH_2), 74.8 (CH), 74.4 (CH_2), 73.7 (CH), 73.5 (CH_2), 72.2 (CH_2), 69.1 (CH_2), 51.0 (CH_2), 47.3 (CH_2), 39.3 (C). MALDI-TOF MS (2855.53): 2879.1 (M^+ + Na), 2895.1 (M^+ + K). Anal. Calcd for $C_{182}H_{180}N_{12}O_{20}$: C, 76.55; H, 6.35; N, 5.89. Found: C, 76.80; H, 6.41; N, 6.08.

1,3,5,7-Tetrakis{4-[1-(3,4,5,7-tetra-*O*-acetyl-2,6-anhydro-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]-phenyl}-adamantane (16b). Route *a*. The cycloaddition between tetraethynyl-adamantane **15** (27 mg, 0.05 mmol) and sugar azide **11b** (116 mg, 0.30 mmol) was carried out as described for the preparation of **10b** to give, after column chromatography on silica gel (1:1 AcOEt/cyclohexane, then AcOEt, finally acetone), first unchanged **11b** (39 mg, 34%). Eluted second was **16b** (96 mg, 92%) as a syrup; $[\alpha]_D$ = +42.5 (*c* 1.1, $CHCl_3$). ^{1}H NMR (300 MHz): δ 7.91 (s, 4H, 4 H-5 Tr.), 7.89−7.84 and 7.62−7.57 (2m, 16H, Ar), 5.46 (dd, 4H, $J_{4,5}$ = 3.3, $J_{5,6}$ = 0.8 Hz, 4 H-5), 5.20 (dd, 4H, $J_{2,3}$ = 10.0, $J_{3,4}$ = 9.9 Hz, 4 H-3), 5.09 (dd, 4H, 4 H-4), 4.72 (dd, 4H, $J_{1a,2}$ = 2.4, $J_{1a,1b}$ = 14.5 Hz, 4 H-1a), 4.40 (dd, 4H, $J_{1b,2}$ = 9.0 Hz, 4 H-1b), 4.25 (dd, 4H, $J_{6,7a}$ = 7.4, $J_{7a,7b}$ = 11.5 Hz, 4 H-7a), 4.02 (dd, 4H, $J_{6,7b}$ = 5.2 Hz, 4 H-7b), 3.89 (ddd, 4H, 4 H-2), 3.85 (ddd, 4H, 4 H-6), 2.26 (bs, 12H, 6 CH_2), 2.19, 2.16, 2.02, and 1.88 (4s, 48H, 16 Ac). ^{13}C NMR (75 MHz): δ 170.3, 170.0, and 169.9 (CO), 149.2 (C Ar), 147.5 (C-4 Tr.), 128.5 (C Ar), 125.7 and 125.5 (CH Ar), 121.4 (C-5 Tr.), 76.8 (CH), 74.7 (CH), 71.5 (CH), 67.5 (CH), 67.2 (CH), 61.6 (C-7), 51.2 (C-1), 47.1 (CH_2), 39.2 (C), 20.8, 20.6, and 20.5 (CH_3CO). MALDI-TOF MS (2086.13): 2088.8 (M^+ + 2H), 2110.7 (M^+ + H + Na), 2126.7 (M^+ + H + K). Anal. Calcd for $C_{102}H_{116}N_{12}O_{36}$: C, 58.73; H, 5.60; N, 8.06. Found: C, 58.89; H, 5.72; N, 8.17.

Route *b*. The *C*-glycocluster **16a** (57 mg, 0.02 mmol) was debenzylated and acetylated as described for the preparation of **7b** to give, after column chromatography on silica gel (AcOEt, then acetone), **16b** (40 mg, 95%) identical to the compound prepared by route *a*.

1,3,5,7-Tetrakis{4-[1-(2,6-anhydro-1-deoxy-D-*glycero*-L-*manno*-heptitol-1-yl)-1*H*-1,2,3-triazol-4-yl]phenyl}-adamantane (16c). The *C*-glycocluster **16b** (42 mg, 0.02 mmol) was deacetylated as described for the preparation of **5c** to give, after a similar workup, **16c** (28 mg, 98%) as an amorphous solid; $[\alpha]_D$ = +3.0 (*c* 0.6, DMF). ^{1}H NMR (300 MHz, DMSO-d_6 + D_2O): δ 7.92 (s, 4H, 4 H-5 Tr.), 7.82 and 7.67 (2d, 16H, J = 8.3 Hz, Ar), 4.78 (dd, 4H, $J_{1a,2}$ = 1.0, $J_{1a,1b}$ = 14.3 Hz, 4 H-1a), 4.37 (dd, 4H, $J_{1b,2}$ = 7.8 Hz, 4 H-1b), 3.68−3.66 (m, 4H), 3.48−3.30 (m, 24H), 2.16 (bs, 12H, 6 CH_2). ^{13}C NMR (75 MHz, DMSO-d_6): δ 149.2 (C), 146.1 (C), 128.6 (C), 125.7 (CH), 125.1 (CH), 78.9 (CH), 78.6 (CH), 74.4 (CH), 68.6 (CH), 68.3 (CH), 60.7 (CH_2), 51.4 (CH_2), 46.3 (CH_2). MALDI-TOF MS (1413.53): 1415.0 (M^+ + H), 1436.9 (M^+ + Na). Anal. Calcd for $C_{70}H_{84}N_{12}O_{20}$: C, 59.48; H, 5.99; N, 11.89. Found: C, 59.20; H, 5.91; N, 11.62.

1-(2,6-Anhydro-3,4,5,7-tetra-*O*-benzyl-1-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-4-phenyl-1*H*-1,2,3-triazole (17a). The cycloaddition between freshly distilled phenylacetylene (55 μL, 0.50 mmol) and sugar azide **8a** (58 mg, 0.10 mmol) was carried out at 80 °C for 24 h as described for the preparation of **10a** to give, after column chromatography on silica gel (from 5:1 to 2:1 cyclohexane/AcOEt), first unchanged **8a** (32 mg, 55%). Eluted second was **17a** (14 mg, 20%) as a white solid. Mp 153−154 °C (AcOEt/cyclohexane); $[\alpha]_D$ = −25.0 (*c* 0.5, $CHCl_3$). ^{1}H NMR (300 MHz): δ 8.00 (s, 1H, H-5 Tr.), 7.80−7.75 (m, 2H, Ar), 7.42−7.26 (m, 21H, Ar), 7.20−7.15 (m, 2H, Ar), 4.96 and 4.92 (2d, 2H, J = 11.5 Hz, PhCH_2), 4.89 and 4.80 (2d, 2H, J = 10.7 Hz, PhCH_2), 4.82 and 4.57 (2d, 2H, J = 10.8 Hz, PhCH_2), 4.73 (dd, 1H, $J_{1a,2}$ = 5.0, $J_{1a,1b}$ = 14.5 Hz, H-1a), 4.67 (dd, 1H, $J_{1b,2}$ = 3.0 Hz, H-1b), 4.63 and 4.56 (2d, 2H, J = 12.0 Hz, PhCH_2), 3.77 (dd, 1H, $J_{3,4}$ = $J_{4,5}$ = 9.0 Hz, H-4), 3.76−3.67 (m, 3H, H-2, 2 H-7), 3.58 (dd, 1H, $J_{5,6}$ = 9.5 Hz, H-5), 3.51 (ddd, 1H, $J_{6,7a}$ = 3.5, $J_{6,7b}$ = 2.1 Hz, H-6), 3.22 (dd, 1H, $J_{2,3}$ = 9.6 Hz, H-3). ^{13}C NMR (100 MHz): δ 147.7 (C-4 Tr.), 138.1, 137.88, 137.80, and 137.76 (C Bn), 130.7 (C Ph), 128.8−127.6 (Ar), 125.6 (C_{ortho} Ph), 121.4 (C-5 Tr.), 86.9 (C-4), 78.7 (C-6), 77.9 (C-5), 77.8 (C-3), 77.1 (C-2), 75.6, 75.15, 75.12, and 73.4 (PhCH_2), 68.8 (C-7), 50.6 (C-1). Anal. Calcd for $C_{43}H_{43}N_3O_5$: C, 75.75; H, 6.36; N, 6.16. Found: C, 75.90; H, 6.46; N, 6.30.

1-(3,4,5,7-Tetra-*O*-acetyl-2,6-anhydro-1-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-4-phenyl-1*H*-1,2,3-triazole (17b). The cycloaddition between freshly distilled phenylacetylene (55 μL, 0.50 mmol) and sugar azide **8b** (39 mg, 0.10 mmol) was carried out at

80 °C for 24 h as described for the preparation of **10a** to give, after column chromatography on silica gel (1:1 cyclohexane/AcOEt), first unchanged **8b** (14 mg, 36%). Eluted second was **17b** (28 mg, 57%) as a white solid. Mp 200−201 °C (AcOEt/cyclohexane); $[\alpha]_D = +21.8$ (*c* 1.0, $CHCl_3$). ^{1}H NMR (300 MHz): δ 7.94 (s, 1H, H-5 Tr.), 7.89−7.85 (m, 2H, H_{ortho} of Ph), 7.48−7.42 (m, 2H, H_{meta} of Ph), 7.38−7.32 (m, 1H, H_{para} of Ph), 5.25 (dd, 1H, $J_{3,4} = J_{4,5} = 9.4$ Hz, H-4), 5.06 (dd, 1H, $J_{5,6} = 10.1$ Hz, H-5), 4.94 (dd, 1H, $J_{2,3} = 10.0$ Hz, H-3), 4.70 (dd, 1H, $J_{1a,2} = 2.4$, $J_{1a,1b} = 14.5$ Hz, H-1a), 4.36 (dd, 1H, $J_{1b,2} = 8.6$ Hz, H-1b), 4.23 (dd, 1H, $J_{6,7a} = 5.6$, $J_{7a,7b} = 12.3$ Hz, H-7a), 4.15 (dd, 1H, $J_{6,7b} = 2.3$ Hz, H-7b), 3.88 (ddd, 1H, H-2), 3.64 (ddd, 1H, H-6), 2.14, 2.05, 2.03, and 1.94 (4s, 12H, 4 Ac). ^{13}C NMR (75 MHz): δ 170.5, 170.1, 169.7, and 169.4 (CO), 147.9 (C-4 Tr.), 130.4 (C_{ipso} Ph), 128.8 (C_{meta} Ph), 128.2 (C_{para} Ph), 125.7 (C_{ortho} Ph), 121.5 (C-5 Tr.), 76.3 (C-2), 76.0 (C-6), 73.6 (C-4), 69.6 (C-3), 68.2 (C-5), 61.7 (7), 51.0 (C-1), 20.7 and 20.5 (CH_3CO). Anal. Calcd for $C_{23}H_{27}N_3O_9$: C, 56.44; H, 5.56; N, 8.58. Found: C, 56.52; H, 5.60; N, 8.69.

1-(2,6-Anhydro-3,4,5,7-tetra-*O*-benzyl-1-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-5-phenyl-1*H*-1,2,3-triazole (18a). A mixture of freshly distilled phenylacetylene (11 μL, 0.10 mmol), sugar azide **8a** (58 mg, 0.10 mmol), commercially available chloro(cyclopentadienyl)bis(triphenylphosphine)ruthenium(II) (7 mg, 0.01 mmol), and anhydrous toluene (1 mL) was stirred at 80 °C for 24 h, then cooled to room temperature, diluted with AcOEt (40 mL), washed with 1 M phosphate buffer at pH 7 (2 × 5 mL), dried (Na_2SO_4), and concentrated. The residue was eluted from a column of silica gel (from 5:1 to 2:1 cyclohexane/AcOEt) to give first unchanged **8a** (9 mg, 15%). Eluted second was a 2:1 mixture of **18a** and **17a** (8 mg, 12%). Eluted third was **18a** (21 mg, 31%) as a syrup; $[\alpha]_D = -7.1$ (*c* 0.6, $CHCl_3$). ^{1}H NMR (300 MHz): δ 7.70 (s, 1H, H-4 Tr.), 7.57−7.53 (m, 2H, Ar), 7.43−7.26 (m, 21H, Ar), 7.20−7.15 (m, 2H, Ar), 5.00 and 4.88 (2d, 2H, $J = 11.1$ Hz, PhCH_2), 4.97 and 4.93 (2d, 2H, $J = 11.2$ Hz, PhCH_2), 4.82 and 4.58 (2d, 2H, $J = 10.8$ Hz, PhCH_2), 4.61 (dd, 1H, $J_{1a,2} = 3.1$, $J_{1a,1b} = 14.5$ Hz, H-1a), 4.46 and 4.40 (2d, 2H, $J = 12.0$ Hz, PhCH_2), 4.36 (dd, 1H, $J_{1b,2} = 7.0$ Hz, H-1b), 3.89 (ddd, 1H, $J_{2,3} = 9.7$ Hz, H-2), 3.77 (dd, 1H, $J_{3,4} = 8.8$, $J_{4,5} = 9.0$ Hz, H-4), 3.64 (dd, 1H, $J_{5,6} = 9.7$ Hz, H-5), 3.62 (dd, 1H, H-3), 3.62 (dd, 1H, $J_{6,7a} = 4.0$, $J_{7a,7b} = 10.8$ Hz, H-7a), 3.56 (dd, 1H, $J_{6,7b} = 1.9$ Hz, H-7b), 3.40 (ddd, 1H, H-6). ^{13}C NMR (100 MHz): δ 139.5 (C-5 Tr.), 138.4 (C Ar), 138.0 (C Ar), 137.9 (C Ar), 132.8 (C-4 Tr.), 129.5−127.2 (Ar), 87.1 (C-4), 79.1 (C-3), 78.7 (C-6), 78.0 (C-5), 77.4 (C-2), 75.5, 75.0, 74.8, and 73.4 (PhCH_2), 68.9 (C-7), 48.3 (C-1). Anal. Calcd for $C_{43}H_{43}N_3O_5$: C, 75.75; H, 6.36; N, 6.16. Found: C, 75.98; H, 6.51; N, 6.38.

1-(3,4,5,7-Tetra-*O*-acetyl-2,6-anhydro-1-deoxy-D-*glycero*-D-*gulo*-heptitol-1-yl)-5-phenyl-1*H*-1,2,3-triazole (18b). The cycloaddition between freshly distilled phenylacetylene (11 μL, 0.50 mmol) and sugar azide **8b** (39 mg, 0.10 mmol) was carried out as described for the preparation of **18a** to give, after column chromatography on silica gel (from 1:1 to 1:2 cyclohexane/AcOEt), **18b** (26 mg, 53%) as a syrup; $[\alpha]_D = +14.0$ (*c* 1.0, $CHCl_3$). ^{1}H NMR (300 MHz): δ 7.71 (s, 1H, H-4 Tr.), 7.51−7.43 (m, 5H, Ph), 5.25 (dd, 1H, $J_{3,4} = 9.4$, $J_{4,5} = 9.3$ Hz, H-4), 5.06 (dd, 1H, $J_{5,6} = 10.2$ Hz, H-5), 4.98 (dd, 1H, $J_{2,3} = 9.9$ Hz, H-3), 4.45 (dd, 1H, $J_{1a,2} = 2.8$, $J_{1a,1b} = 14.4$ Hz, H-1a), 4.35 (dd, 1H, $J_{1b,2} = 8.8$ Hz, H-1b), 4.18 (ddd, 1H, H-2), 4.14 (dd, 1H, $J_{6,7a} = 5.0$, $J_{7a,7b} = 12.4$ Hz, H-7a), 3.93 (dd, 1H, $J_{6,7b} = 2.2$ Hz, H-7b), 3.59 (ddd, 1H, H-6), 2.10, 2.04, 2.03, and 2.02 (4s, 12H, 4 Ac). ^{13}C NMR (75 MHz): δ 170.4, 170.1, 169.9, and 169.4 (CO), 139.5 (C-5 Tr.), 132.9 (C-4 Tr.), 129.5 (C_{para} Ph), 129.2 and 128.9 (C_{ortho}, C_{meta} Ph), 126.7 (C_{ipso} Ph), 76.8 (C-2), 75.5 (C-6), 73.7 (C-4), 70.2 (C-3), 68.1 (C-5), 61.7 (7), 48.8 (C-1), 20.6 and 20.5 (CH_3CO). Anal. Calcd for $C_{23}H_{27}N_3O_9$: C, 56.44; H, 5.56; N, 8.58. Found: C, 56.72; H, 5.69; N, 8.78.

Supporting Information Available: ^{1}H and ^{13}C spectra for all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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