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Geminal Diazides Derived from 1,3-Dicarbonyls: A Protocol for Synthesis

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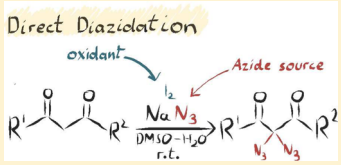
Supporting Information

ABSTRACT: Geminal diazides constitute a rare class of compounds where only a limited number of methods are available for their synthesis. We present the reaction of 1,3-dicarbonyl compounds (as exemplified by malonates, 3-oxoesters, and 1,3-diketones) with molecular iodine and sodium azide in aqueous DMSO providing a general access to geminal diazides. A broad range of geminal diazides with various structural motifs including sterically demanding substituents and ordinary functional groups were synthesized, and it was shown that the diazidation of 1,3-dicarbonyls can be selectively achieved even in the presence of other 1,3-dicarbonyls with substituents at 2-position. Additionally, several diazides were studied regarding their thermal stability.



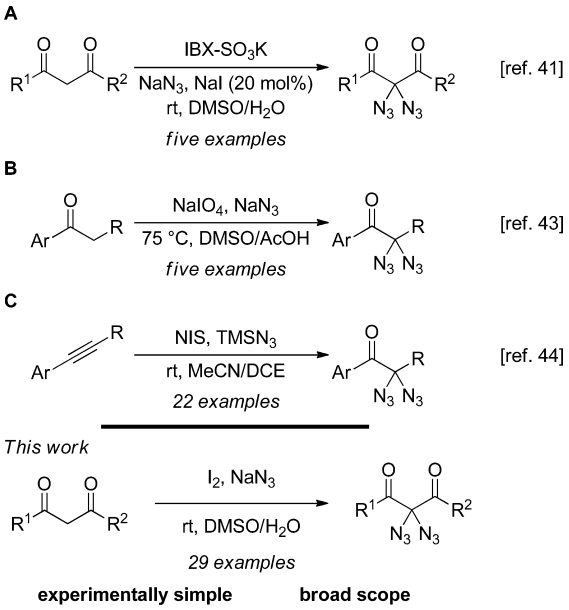
INTRODUCTION

While organic azides[1,2] have evolved into a major field of contemporary organic synthesis, in particular due to their manifold of applications in chemical biology[3−7] and materials science,[8−10] geminal diazides are a somewhat neglected class of compounds. In a breathtaking study from 1908, Forster and co-workers reported the probably first geminal diazide, ethyl 2,2-diazidoacetate $CH(N_3)_2CO_2Et$;[11] the synthesis of ethyl 2,2-diazidomalonate $(N_3)_2C(CO_2Et)_2$ was described in 1910.[12,13] Thereafter, members of the compound class made not more than sporadic appearances in the literature,[14−16] and the majority of the publications that somehow included geminal diazides had a research focus where the diazides were mostly innocent bystanders.[17]

To our surprise, the number of reports pointing toward synthetic applications or useful properties of geminal diazides was shockingly rare; the few reports we found through our review of the literature were hardly cited.[18−20] As an exception, a few preliminary studies were performed that described the reactivity of selected geminal diazides under irradiation[21−23] or heat.[24−26] This lack of interest may have partly arisen from their supposedly hazardous character.[27] On the other hand, only a small number of methods were known to generate molecules with two azido groups attached to one carbon atom before 2012, and most of those methods relied on the classical treatment of geminal dihalides with sodium azide.[28−30] Other less common methods leading to geminal diazides comprise the use of trimethylsilylazide,[31−34] iodine azide,[35] polymeric ammonium azide,[36] or aryl sulfonazides.[37]

Recently, we initiated a project that would uncover novel reactivities and synthetic applications of geminal diazides. To this end, we required a straightforward and experimentally simple approach toward the title class of compounds. Our seminal report from 2012 on the oxidative azidation of enolizable carbonyls included five examples where geminal diazides were obtained from the simple treatment of 1,3-dicarbonyls with IBX-SO_3K,[38−40] sodium azide, and catalytic amounts of sodium iodide in aqueous DMSO at room temperature (Scheme 1A).[41] The mild reaction conditions tolerated a range of functional groups; yields were typically high. A variation of this procedure also allowed for the synthesis of geminal triazides, highly energetic compounds that must be handled with great caution.[42] At the same time, Sudalai and

Scheme 1. Recent Diazidation Protocols



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co-workers reported how several aryl ketones can be efficiently diazidated by the use of sodium periodate and sodium azide in a hot mixture of DMSO and acetic acid (Scheme 1B).[43] In 2015, it was shown by Yanada and co-workers that alkynes reacted with *N*-iodosuccinimide and trimethylsilyl azide, leading to 2,2-diazidoketones (Scheme 1C).[44] While this method is arguably the most versatile one, it only provides access to a full spectrum of diazidated aryl ketones; a flexible method for the synthesis of the diazidated variants of functionalized alkyl ketones is still desirable.

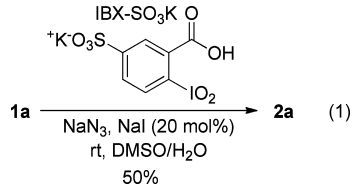
Herein, we present an experimentally simple method for the diazidation of 1,3-dicarbonyl compounds. Geminal diazides with various functional groups were directly accessed by employing molecular iodine and sodium azide in aqueous DMSO at room temperature. We also show that the diazides are relatively stable, a promise for future applications.

RESULTS AND DISCUSSION

Based on our previous diazidation protocol with IBX-SO_3K,[41] we began our study with the reaction of malonate **1a** in the presence of sodium azide, the most abundant and cheapest azide source, and it was found early that aqueous solutions of DMSO or THF were required to observe diazidated products, most likely due to the low solubility of sodium azide in purely organic solvents. Gratifyingly, molecular iodine was identified as a suitable oxidant and, when using aqueous DMSO, gave the desired diazide **2a** in promising 65% yield. In order to generate a full range of geminal diazides derived from 1,3-dicarbonyls, the reaction of 1,3-dicarbonyls **1** with iodine and sodium azide was typically performed in aqueous DMSO at room temperature: **1**, I_2 (2.2 equiv), NaN_3 (6.0 equiv), rt, DMSO/H_2O (2:1, 0.1 M). As shown in Table 1, a variety of malonates (e.g., **1a**–**d**) gave the corresponding diazide products (**2a**–**d**) under the reaction conditions. To our delight, the sterically demanding *tert*-butyl diazidomalonate **2c** was likewise obtained in acceptable 51% yield (entry 3). The diazidation of several acyl acetates was also possible and proved quite robust with regard to bulky R^1 groups: Substrates bearing cyclohexyl, *tert*-butyl, or, even more impressive, adamantyl groups were reactive (entries 10–12). Besides acyl acetates with R^1 being an alkyl group, a variety of aryl ketones with electron-rich and electron-poor substituents at the aryl core R^1 were suitable substrates (entries 13–17). It is worth mentioning that the diazidation protocol works well in the presence of a multitude of functional groups including olefins (e.g., **2r** and **2s**), ethers (e.g., **2t**), esters (e.g., **2u**), silyl ethers (e.g., **2v**), and azides (e.g., **2w**). Of relevance, tertiary and secondary alcohols were tolerated without the need for protecting groups (entries 24 and 25). The 1,3-dicarbonyls **1z** and **1aa**, derived from enantiomerically pure Boc-protected amino acids, delivered the desired diazides **2z** and **2aa** without racemization. Furthermore, amide **1ab** and diketone **1ac** gave rise to their corresponding diazides, thus highlighting our impression that we have a method with broad scope in hand.

In an early competition experiment with a 1:1 mixture of acetylacetate **1g** and the analogous acetylacetate **3** having an additional methyl group, we observed an outstanding selectivity for the diazidated product **2g** under our azidation conditions (Scheme 2). According to ^1H NMR of the crude mixture, the monoazidated compound **4** was not formed; we assume that azide **4** might be an intermediate that is further azidated with a markedly increased rate under the reaction conditions to finally provide **2g**. Even more important, the methylated acetylacetate **3** remained fully untouched, and the corresponding monoazide **5** was not found. This result leads to the conclusion that, likely for steric reasons, it is possible to perform the selective diazidation of 1,3-dicarbonyls in the presence of other 1,3-dicarbonyls with substituents at 2-position.

We again point out that all of the diazides summarized in Table 1 are also available by using our traditional diazidation protocol (3 equiv of IBX-SO_3K, 0.2 equiv of NaI, 3.3 equiv of NaN_3, rt, DMSO/H_2O).[41] An example with IBX-SO_3K as oxidizing agent instead of iodine is shown in eq 1. Due to the fact that the use of IBX-SO_3K requires a three-step synthesis of the reagent, however, we recommend to test our current conditions with the iodine–sodium azide couple first when attempting the diazidation of 1,3-dicarbonyls.



(1)

We assume that, under our reaction conditions, iodine (or IN_3) is the electrophilic iodine source that leads to the iodination of the easily enolizable 1,3-dicarbonyl system under formation of **A** (Scheme 3). Subsequent nucleophilic substitution gives the monoazide **B**, which undergoes a second, probably more rapid, iodination (giving **C**) followed by the second azide introduction. However, at this stage of our studies, we cannot rule out a radical mechanism.

The structure of diazide **2m** was determined using X-ray crystallographic analysis (see Supporting Information).[45] The structures of all the geminal diazides **2a**–**ac** were ascertained on the basis of spectroscopic data. The IR spectra typically showed a dominant azide stretching frequency around 2110 cm^{-1}. In the ^{13}C NMR spectra, the quaternary carbons attached to the two azide groups had distinguished chemical shifts ranging from 80 to 87 ppm (in $CDCl_3$). The diazides **2** in the present study were derivatized with either cyclooctyne or phenylacetylene to obtain the corresponding bis-triazoles through Huisgen cycloaddition; their full characterization by NMR and IR techniques as well as by high resolution mass spectrometry provided unequivocal support for the identity of the diazide title compounds (see Supporting Information). Greatly to our surprise, however, the direct measurement of the accurate mass of several geminal diazides (i.e., **2b**, **2c**, **2d**, **2r**, **2x**, **2z**, **2aa**) was rendered possible by standard ESI techniques. We reasoned that the geminal diazides derived from 1,3-dicarbonyls must be considered to be relatively stable.

With the goal to roughly estimate safety issues when handling geminal diazides, we decided to briefly investigate the thermal behavior of a small number of selected compounds, **2c**, **2g**, **2m**, and **2ac**. The thermal stabilities were determined from TGA and DSC measurements in sealed Al pans using a nitrogen flow of 30 mL/min at a heating rate of 5 K/min. The decomposition temperatures are given as onset temperatures (Table 2). In all cases, no defined melting points (or boiling points) were found. Instead, all the selected diazides show similar thermal stability with decomposition temperatures ranging from 118 to 156 °C. Thermolysis products were not identified,[24−26] and the pathway of decomposition was not further studied.

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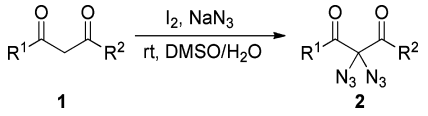
Table 1. Synthesis of Diazides 2 from 1,3-Dicarbonyls 1



1 2

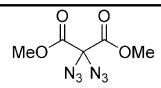
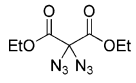
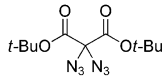
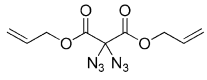
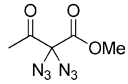
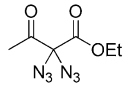
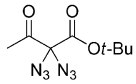
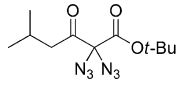
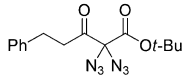
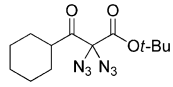
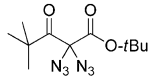
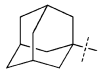
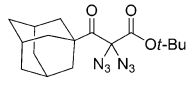
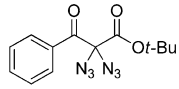
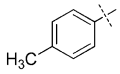
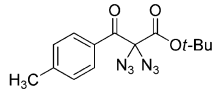
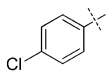
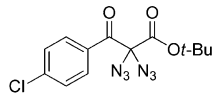
Entry	Substrate 1 R^1	Substrate 1 R^2	#	Product 2	Yield [%][a]
1[b,d]	OMe	OMe	**a**		65
2[b,d]	OEt	OEt	**b**		61
3[b]	O*t*-Bu	O*t*-Bu	**c**		51
4[b]	OAllyl	OAllyl	**d**		30
5[b]	Me	OMe	**e**		88
6[b]	Me	OEt	**f**		88
7[b]	Me	O*t*-Bu	**g**		93
8[b]	*i*-Bu	O*t*-Bu	**h**		89
9[b]		O*t*-Bu	**i**		50
10[c]		O*t*-Bu	**j**		72
11[c]	*t*-Bu	O*t*-Bu	**k**		67
12[c]		O*t*-Bu	**l**		50
13[b]		O*t*-Bu	**m**		93
14[c]		O*t*-Bu	**n**		59
15[c]		O*t*-Bu	**o**		75

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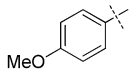
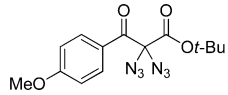
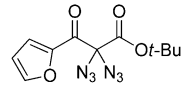
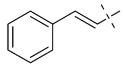
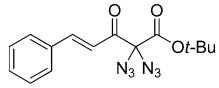
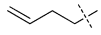
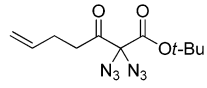
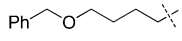
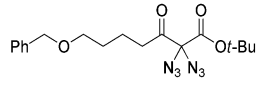
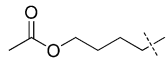
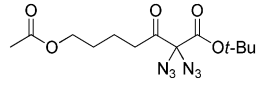
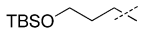
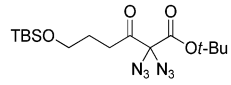
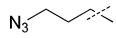
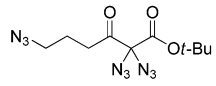
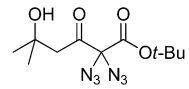
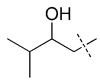
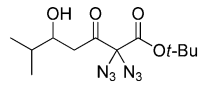
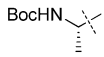
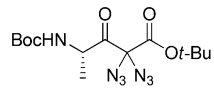
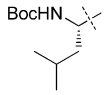
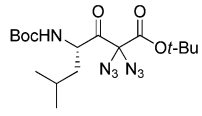
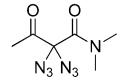
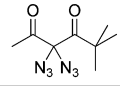
Table 1. continued

Entry	Substrate **1** R^1	Substrate **1** R^2	#	Product **2**	Yield [%][a]
16[c]		O*t*-Bu	**p**		77
17[c]		O*t*-Bu	**q**		64
18[b]		O*t*-Bu	**r**		77
19[c]		O*t*-Bu	**s**		61
20[b]		O*t*-Bu	**t**		65
21[c]		O*t*-Bu	**u**		56
22[c]		O*t*-Bu	**v**		72
23[c]		O*t*-Bu	**w**		81
24[b]		O*t*-Bu	**x**		78
25[b]		O*t*-Bu	**y**		76
26[b,e]		O*t*-Bu	**z**		70
27[b,e]		O*t*-Bu	**aa**		79
28[b]	Me	$N(Me)_2$	**ab**		50
29[b]	Me	*t*-Bu	**ac**		73

[a]Isolated yield after chromatography. [b]I_2 (2.0−2.2 equiv), NaN_3 (3.3−10.0 equiv), rt, DMSO/H_2O (2:1, 0.1 M). [c]I_2 (2.0−2.2 equiv), NaN_3 (4.0−10.0 equiv), $NaHCO_3$ (4.0 equiv), rt, DMSO/H_2O (2:1, 0.1 M). [d]Reaction was carried out at 50 °C. [e]96% ee for **2z**, 93% ee for **2aa**.

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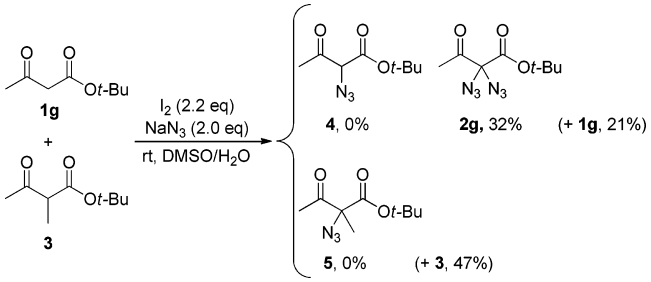
Scheme 2. Selectivity of the Diazidation of a 1:1 Mixture of 1,3-Dicarbonyls 1g and 3 with I_2/NaN_3[a]



[a]Product distribution determined via ^{1}H NMR of the crude mixture.

Scheme 3. Possible Mechanism for the Diazidation of 1,3-Dicarbonyls by Use of Molecular Iodine and Sodium Azide

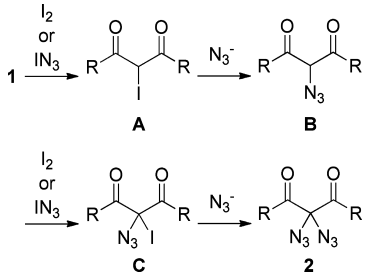


Table 2. Decomposition Temperatures of Geminal Diazides 2c, 2g, 2m, and 2ac

	2c	2g	2m	2ac
T_{dec} [°C]	155.5	142.7	143.5	118.0

CONCLUSION

In conclusion, a novel and mild method for the synthesis of geminal diazides through the direct double azidation of 1,3-dicarbonyl compounds was presented. Further studies regarding the direct diazidation of simple ketones and 2-aryl ketones are currently under investigation. Our protocol now gives access to a broad range of previously undisclosed diazides, many of which contain uncommon groups with sensitive functionalities or exceptional steric bulk. We also provided evidence that the geminal diazides are relatively stable having decomposition temperatures higher than 100 °C. This paper aims to encourage researchers to synthesize and further utilize members of this promising class of compounds.

CAUTION! We underline that geminal diazides are still potentially hazardous chemicals that should be handled with care.

EXPERIMENTAL SECTION

All commercial reagents were used as received. Thin-layer chromatography (TLC) was conducted with coated glass backed plates (silica gel 60 F_{254}) and visualized by exposure to UV light (254 nm) or by staining with ceric ammonium molybdate (CAM), potassium permanganate ($KMnO_4$), or iodine (I_2). Flash chromatography was performed on silica gel (43−60 μm); the used eluent is reported in parentheses (PE, petroleum ether; CH, cyclohexane). ^{1}H NMR spectra were recorded at 400 or 600 MHz. ^{13}C NMR spectra were recorded at 101 or 151 MHz. Chemical shifts are reported in ppm. The spectra were calibrated relative to the solvent signal. Multiplicity is indicated as follows: s (singlet); d (doublet); t (triplet); q (quartet); p (pentet); m (multiplet); dd (doublet of doublets); tt (triplet of triplets). IR spectra were recorded using ATR technique. High resolution mass spectra were obtained using ESI ionization methods on a TOF analyzer.

CAUTION! Geminal diazides should be handled with care. The heating bath of the rotary evaporator was set to 40 °C.

General Procedure A for the Preparation of Geminal Diazides 2. The 1,3-dicarbonyl compound **1** was dissolved in a 2:1 mixture of DMSO and water (0.1 M). Sodium azide (3.3−10.0 equiv) and iodine (2.05−3.00 equiv) were added consecutively. The reaction mixture was stirred at room temperature until TLC indicated complete consumption of the starting material. A saturated aqueous solution of sodium thiosulfate was added, and the mixture was diluted with water and extracted with ethyl acetate. The combined organic phases were dried over magnesium sulfate. Evaporation of the solvent *in vacuo* and flash chromatography on silica gel afforded the corresponding geminal diazides **2**.

General Procedure B for the Preparation of Geminal Diazides 2. The 1,3-dicarbonyl **1** compound was dissolved in a 2:1 mixture of DMSO and water (0.1 M). Sodium azide (4.0 equiv), sodium bicarbonate (4.0 equiv), and iodine (2.2 equiv) were added consecutively. The reaction mixture was stirred at room temperature until TLC indicated complete consumption of the starting material. A saturated aqueous solution of sodium thiosulfate was added, and the mixture was diluted with water and extracted with ethyl acetate. The combined organic phases were dried over magnesium sulfate. Evaporation of the solvent *in vacuo* and flash chromatography on silica gel afforded the corresponding geminal diazides **2**.

General Procedure C for the Cycloaddition Reaction with Phenyl Acetylene. The geminal diazide **2** was dissolved in a 2:1 mixture of *t*BuOH and water (0.3 M). Phenyl acetylene (2.2 equiv), copper(II) sulfate pentahydrate (0.20 equiv), sodium L-ascorbate (0.40 equiv), and tris[(1-benzyl-1*H*-1,2,3-triazol-4-yl)methyl]amine (TBTA, 0.01 equiv) were added consecutively. The reaction mixture was stirred at room temperature until TLC indicated complete consumption of the starting material. Water was added, and the mixture was extracted with ethyl acetate. The combined organic phases were dried over magnesium sulfate. Evaporation of the solvent *in vacuo* and flash chromatography on silica gel afforded the corresponding geminal bistriazole.

General Procedure D for the Cycloaddition with Cyclooctyne. The geminal diazide **2** was dissolved in dichloromethane (0.1 M), and cyclooctyne (4.0 equiv) was added. The solution was stirred at room temperature until TLC indicated complete consumption of the starting material. Evaporation of the solvent *in vacuo* and flash chromatography on silica gel afforded the corresponding geminal bistriazole.

*Dimethyl 2,2-Diazidomalonate (**2a**).* Following general procedure A (0.200 g of of **1a**, 2 h 50 °C, 13 h rt, 3.3 equiv of NaN_3, 3.0 equiv of I_2), dimethyl 2,2-diazidomalonate **2a** was obtained as a colorless liquid (0.207 g, 0.97 mmol, 65%) after chromatography (PE/EtOAc 100/0 → 80/20). TLC: R_f = 0.54 (PE/EtOAc 80/20, [$KMnO_4$]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 3.92 (s, 6H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 164.1, 80.1, 54.6. IR: 2962, 2115, 1756, 1437, 1295, 1225, 1068, 1046, 1007, 937, 826, 788, 740, 628, 594, 549, 471 [cm^{-1}]. For HRMS, **2a** was converted to the bistriazole according to general procedure C (0.030 g of of **2a**, 1 h). Dimethyl 2,2-bis(4-phenyl-1*H*-1,2,3-triazol-1-yl)malonate was obtained as a white solid (0.057 g, 0.14 mmol, 97%) after chromatography (PE/EtOAc 100/0 → 80/20). TLC: R_f = 0.21 (PE/EtOAc 80/20), [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 8.46 (s, 2H), 7.84−7.79 (m, 4H), 7.45−7.38 (m, 4H), 7.37−7.31 (m, 2H), 4.09 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 161.2, 148.5, 129.5, 129.0, 128.9, 126.1, 120.6, 79.7, 55.4. HRMS: (m/z) calculated for [$C_{21}H_{18}N_6O_4Na^+$] 441.1282, found 441.1266.

*Diethyl 2,2-Diazidomalonate (**2b**).* Following general procedure A (2.100 g of of **1b**, 50 °C, overnight, 3.0 equiv of NaN_3, 3.0 equiv of I_2), diethyl 2,2-diazidomalonate **2b** was obtained as a colorless liquid (1.950 g, 8.05 mmol, 61%) after chromatography (PE/Et_2O 90/10). TLC: R_f = 0.73 (PE/Et_2O 80/20, [I_2]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 4.42−4.33 (m, 4H), 1.40−1.31 (m, 6H). ^{13}C NMR

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(151 MHz, $CDCl_3$): δ [ppm] 163.7, 80.0, 64.2, 14.1. IR: 2987, 2942, 2910, 2876, 2118, 1754, 1468, 1447, 1370, 1298, 1216, 1043, 855, 771, 549 [cm^{-1}]. HRMS: (*m*/*z*) calculated for [$C_7H_{10}N_6O_4Na^+$] 265.0656, found 265.0652.

*Di-tert-butyl 2,2-Diazidomalonate (**2c**).* Following general procedure A (1.892 g of **1c**, 50 °C, overnight, 3.3 equiv of NaN_3, 3.0 equiv of I_2), di-*tert*-butyl 2,2-diazidomalonate **2c** was obtained as a colorless liquid (1.320 g, 4.43 mmol, 51%) after chromatography (PE/Et_2O 95/5). TLC: R_f = 0.91 (PE/Et_2O 80/20, [I_2]). ^1H NMR (400 MHz, $CDCl_3$): δ [ppm] 1.54 (s, 18H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 162.6, 86.1, 80.2, 27.9; IR: 2982, 2937, 2119, 1750, 1477, 1459, 1396, 1371, 1239, 1143, 1031, 834, 723, 549, 466 [cm^{-1}]. HRMS: (*m*/*z*) calculated for [$C_{11}H_{18}N_6O_4Na^+$] 321.1282, found 321.1281.

*Diallyl 2,2-Diazidomalonate (**2d**).* Following general procedure A (2.270 g of **1d**, 50 °C, overnight, 3.3 equiv of NaN_3, 3.0 equiv of I_2), diallyl 2,2-diazidomalonate **2d** was obtained as a colorless liquid (0.980 g, 3.68 mmol, 30%) after chromatography (PE/Et_2O 90/10). TLC: R_f = 0.71 (PE/Et_2O 80/20, [I_2]). ^1H NMR (400 MHz, $CDCl_3$): δ [ppm] 5.91 (ddt, *J* = 17.1, 10.4, 5.8 Hz, 2H), 5.40 (dd, *J* = 17.2, 1.4 Hz, 2H), 5.33 (dd, *J* = 10.4, 1.2 Hz, 2H), 4.78 (d, *J* = 5.9 Hz, 4H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 163.4, 130.2, 120.5, 80.1, 68.4. IR: 3092, 3026, 2989, 2958, 2887, 2118, 1755, 1650, 1452, 1424, 1363, 1218, 991, 936, 788, 548 [cm^{-1}]. HRMS: (*m*/*z*) calculated for [$C_9H_{10}N_6O_4Na^+$] 289.0656, found 289.0640.

*Methyl 2,2-Diazido-3-oxobutanoate (**2e**).* Following general procedure A (2.042 g of **1e**, overnight, 10.0 equiv of NaN_3, 2.2 equiv of I_2), methyl 2,2-diazido-3-oxobutanoate **2e** was obtained as a colorless liquid (3.065 g, 15.47 mmol, 88%) after chromatography (PE/Et_2O 90/10). TLC: R_f = 0.55 (PE/Et_2O 90/10, [I_2]). ^1H NMR (400 MHz, $CDCl_3$): δ [ppm] 3.90 (s, 3H), 2.26 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 195.5, 164.9, 83.3, 54.4, 25.0. IR: 2962, 2110, 1743, 1436, 1359, 1274, 1225, 1069, 1038, 1014, 983, 943, 916, 807, 765, 745, 697, 668, 648, 582, 556, 543, 460, 428 [cm^{-1}]. For HRMS, **2e** was converted to the bistriazole according to general procedure D (0.100 g of **2e**, overnight). Methyl 2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-3-oxobutanoate was obtained as a white solid (0.178 g, 0.43 mmol, 85%) after chromatography (PE/EtOAc 70/30). TLC: R_f = 0.42 (PE/EtOAc 70/30), [UV]). ^1H NMR (600 MHz, $CDCl_3$): δ [ppm] 4.04 (s, 3H), 2.90−2.85 (m, 4H), 2.59 (s, 3H), 2.24−2.13 (m, 4H), 1.76−1.69 (m, 4H), 1.42−1.29 (m, 12H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 188.8, 162.4, 146.3, 136.6, 86.2, 54.7, 28.8, 27.6, 26.2, 25.7, 25.1, 24.4, 21.9. HRMS: (*m*/*z*) calculated for [$C_{21}H_{30}N_6O_3Na^+$] 437.2272, found 437.2272.

*Ethyl 2,2-Diazido-3-oxobutanoate (**2f**).* Following general procedure A (4.084 g of **1f**, 2 h, 10.0 equiv of NaN_3, 2.2 equiv of I_2), ethyl 2,2-diazido-3-oxobutanoate **2f** was obtained as a colorless liquid (5.861 g, 27.62 mmol, 88%) after chromatography (PE/Et_2O 100/0 → 90/10). TLC: R_f = 0.59 (PE/Et_2O 90/10, [I_2]). ^1H NMR (600 MHz, $CDCl_3$): δ [ppm] 4.37 (q, *J* = 7.1 Hz, 2H), 2.28 (s, 3H), 1.36 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 195.6, 164.3, 83.3, 64.3, 25.1, 14.1. IR: 2985, 2112, 1743, 1359, 1222, 1068, 1008, 942, 853, 747, 582, 544 [cm^{-1}]. For HRMS, **2f** was converted to the bistriazole according to general procedure D (0.100 g of **2f**, overnight). Ethyl 2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-3-oxobutanoate was obtained as a viscous oil (0.129 g, 0.30 mmol, 64%) after chromatography (PE/EtOAc 70/30). TLC: R_f = 0.45 (PE/EtOAc 70/30, [UV]). ^1H NMR (600 MHz, $CDCl_3$): δ [ppm] 4.56−4.49 (m, 2H), 2.91−2.84 (m, 4H), 2.63−2.59 (m, 3H), 2.27−2.14 (m, 4H), 1.78−1.69 (m, 4H), 1.44−1.28 (m, 15H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 188.9, 161.7, 146.2, 136.6, 86.3, 64.8, 28.9, 27.6, 26.2, 25.7, 25.1, 24.4, 21.9, 13.8. HRMS: (*m*/*z*) calculated for [$C_{22}H_{32}N_6O_3Na^+$] 451.2428, found 451.2408.

*tert-Butyl 2,2-Diazido-3-oxobutanoate (**2g**).* Following general procedure A (1.000 g of **1g**, 90 min, 10.0 equiv of NaN_3, 2.2 equiv of I_2), *tert*-butyl 2,2-diazido-3-oxobutanoate **2g** was obtained as a colorless liquid (1.370 g, 5.70 mmol, 93%) after chromatography (PE/EtOAc 100/0 → 80/20). TLC: R_f = 0.57 (PE/EtOAc 90/10, [$KMnO_4$]). ^1H NMR (400 MHz, $CDCl_3$): δ [ppm] 2.26 (s, 3H), 1.54 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 195.8, 163.1, 86.9, 83.6, 28.0, 25.1. IR: 2984, 2937, 2112, 1742, 1476, 1459, 1419, 1397, 1372, 1358, 1281, 1238, 1192, 1145, 1070, 1036, 1013, 966, 942, 831, 772, 749, 668, 644, 582, 557, 544, 468, 436 [cm^{-1}]. For HRMS, **2g** was converted to the bistriazole according to general procedure C (0.030 g of **2g**, 0.16 M, overnight). *tert*-Butyl 3-oxo-2,2-bis(4-phenyl-1*H*-1,2,3-triazol-1-yl)-butanoate was obtained as a white solid (0.037 g, 0.08 mmol, 67%) after chromatography (PE/EtOAc 100/0 → 50/50). TLC: R_f = 0.46 (PE/EtOAc 70/30, [UV]). ^1H NMR (600 MHz, $CDCl_3$): δ [ppm] 8.31 (s, 2H), 7.83−7.79 (m, 4H), 7.43−7.38 (m, 4H), 7.36−7.31 (m, 2H), 2.55 (s, 3H), 1.65 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 188.8, 159.6, 148.3, 129.6, 129.0, 128.9, 126.0, 120.9, 88.9, 83.7, 27.8, 26.7. HRMS: (*m*/*z*) calculated for [$C_{24}H_{24}N_6O_3Na^+$] 467.1802, found 467.1794.

*tert-Butyl 2,2-Diazido-5-methyl-3-oxohexanoate (**2h**).* Following general procedure A (1.100 g of **1h**, 3 h, 10.0 equiv of NaN_3, 2.2 equiv of I_2), *tert*-butyl 2,2-diazido-5-methyl-3-oxohexanoate **2h** was obtained as a colorless liquid (1.260 g, 4.45 mmol, 89%) after chromatography (CH/EtOAc 100/0 → 90/10). TLC: R_f = 0.48 (CH/EtOAc 90/10, [$KMnO_4$]).[1]^1H NMR (400 MHz, $CDCl_3$): δ [ppm] 2.42 (d, *J* = 6.8 Hz, 2H), 2.26−2.14 (m, 1H), 1.53 (s, 9H), 0.93 (d, *J* = 6.7 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 197.8, 163.1, 86.8, 83.5, 46.3, 27.9, 24.1, 22.5. IR: 2962, 2937, 2875, 2114, 1742, 1468, 1397, 1371, 1239, 1144, 1103, 1049, 999, 982, 934, 831, 754, 707, 625, 555, 545, 468, 436 [cm^{-1}]. For HRMS, **2h** was converted to the bistriazole according to general procedure D (0.027 g of **2h**, 3.5 h, $CDCl_3$). *tert*-Butyl 2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-5-methyl-3-oxohexanoate was obtained as a yellow liquid. TLC: R_f = 0.19 (CH/EtOAc 80/20, [UV]). ^1H NMR (400 MHz, $CDCl_3$): δ [ppm] 2.98−2.91 (m, 2H), 2.91−2.84 (m, 4H), 2.44−2.31 (m, 1H), 2.27−2.13 (m, 4H), 1.78−1.69 (m, 4H), 1.59 (s, 9H), 1.42−1.27 (m, 12H), 1.06 (d, *J* = 6.7 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 191.8, 160.4, 145.8, 136.6, 87.7, 86.8, 49.4, 27.8, 27.6, 26.1, 25.7, 25.6, 25.1, 24.4, 23.1, 22.0. HRMS (*m*/*z*) calculated for [$C_{27}H_{43}N_6O_3^+$] 499.3391, found 499.3389.

*tert-Butyl 2,2-Diazido-3-oxo-5-phenylpentanoate (**2i**).* Following general procedure A (1.250 g of **1i**, 3 h, 10.0 equiv of NaN_3, 2.2 equiv of I_2), *tert*-butyl 2,2-diazido-3-oxo-5-phenylpentanoate **2i** was obtained as a yellowish liquid (0.830 g, 2.51 mmol, 50%) after chromatography (CH/EtOAc 100/0 → 90/10). TLC: R_f = 0.46 (CH/EtOAc 90/10, [$KMnO_4$]). ^1H NMR (600 MHz, $CDCl_3$): δ [ppm] 7.32−7.27 (m, 2H), 7.23−7.17 (m, 3H), 2.98−2.92 (m, 2H), 2.92−2.86 (m, 2H), 1.48 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 197.6, 163.0, 140.2, 128.7, 128.5, 126.6, 86.9, 83.4, 39.4, 29.4, 27.9. IR: 3029, 2982, 2934, 2113, 1742, 1455, 1372, 1237, 1149, 1056, 1028, 1007, 830, 746, 698 [cm^{-1}]. For HRMS, **2i** was converted to the bistriazole according to general procedure D (0.035 g, 3.5 h), *tert*-butyl 2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-3-oxo-5-phenylpentanoate was obtained as a colorless liquid. TLC: R_f = 0.37 (CH/EtOAc 80/20, [UV]). ^1H NMR (400 MHz, $CDCl_3$): δ [ppm] 7.30−7.16 (m, 5H), 3.22 (s, 4H), 2.92−2.85 (m, 4H), 2.23−2.16 (m, 4H), 1.77−1.68 (m, 4H), 1.59 (s, 9H), 1.41−1.34 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 192.0, 160.1, 145.9, 140.4, 136.6, 128.7, 128.4, 126.5, 87.9, 86.8, 43.5, 31.6, 27.8, 27.6, 26.1, 25.8, 25.0, 24.4, 22.0. HRMS (*m*/*z*) calculated for [$C_{31}H_{43}N_6O_3^+$] 547.3391, found 547.3391.

*tert-Butyl 2,2-Diazido-3-cyclohexyl-3-oxopropanoate (**2j**).* Following general procedure B (1.000 g of **1j**, 3 h), *tert*-butyl 2,2-diazido-3-cyclohexyl-3-oxopropanoate **2j** was obtained as a colorless liquid (0.987 g, 3.20 mmol, 72%) after chromatography (CH/EtOAc 100/0 → 93/7). TLC: R_f = 0.51 (CH/EtOAc 90/10, [$KMnO_4$]). ^1H NMR (400 MHz, C_6D_6): δ [ppm] 2.67 (tt, *J* = 11.4, 3.4 Hz, 1H), 1.88−1.79 (m, 2H), 1.58−1.46 (m, 2H), 1.45−1.33 (m, 3H), 1.19 (s, 9H), 1.08−0.96 (m, 3H). ^{13}C NMR (101 MHz, C_6D_6): δ [ppm] 201.1, 163.6, 86.2, 83.8, 46.7, 29.5, 27.6, 25.7, 25.6. IR: 2982, 2935, 2857, 2114, 1737, 1451, 1372, 1237, 1144, 1057, 951, 833, 802, 547 [cm^{-1}]. For HRMS, **2j** was converted to the bistriazole according to general procedure D (0.025 g of **2j**, 3 h). *tert*-Butyl 3-cyclohexyl-2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-3-oxopropanoate was obtained as a colorless liquid (0.041 g, 0.08 mmol, 98%) after chromatography (CH/EtOAc 90/10 → 80/20).

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TLC: R_f = 0.36 (CH/EtOAc 80/20, [UV, $KMnO_4$]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 2.90−2.83 (m, 4H), 2.80 (tt, J = 11.3, 2.9 Hz, 1H), 2.48−2.37 (m, 2H), 2.20−2.07 (m, 4H), 1.84−1.76 (m, 2H), 1.75−1.66 (m, 5H), 1.64−1.60 (m, 10H), 1.40−1.21 (m, 16H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 197.1, 160.2, 145.8, 136.6, 88.2, 87.3, 50.9, 32.2, 27.9, 27.6, 26.1, 26.0, 25.9, 25.8, 25.1, 24.5, 22.2. HRMS (m/z) calculated for [$C_{29}H_{44}N_6O_3Na^+$] 547.3367, found 547.3359.

*tert-Butyl 2,2-Diazido-4,4-dimethyl-3-oxopentanoate (**2k**).* Following general procedure B (0.600 g of **1h**, 3 h), *tert*-butyl 2,2-diazido-4,4-dimethyl-3-oxopentanoate **2k** was obtained as colorless liquid (0.566 g, 2.00 mmol, 67%) after chromatography (CH/EtOAc 98/2). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 1.54 (s, 9H), 1.26 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 202.6, 163.3, 86.8, 83.4, 44.7, 28.0, 27.5. IR: 2980, 2938, 2876, 2112, 1754, 1726, 1481, 1459, 1396, 1372, 1235, 1149, 1106, 1058, 920, 832, 547 [cm^{-1}]. For HRMS, **2k** was converted to the bistriazole according to general procedure D (0.026 g of **2k**, overnight). *tert*-Butyl 2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-4,4-dimethyl-3-oxopentanoate was obtained as a colorless liquid (0.037 g, 0.07 mmol, 82%) after chromatography (CH/EtOAc 90/10 → 80/20). TLC: R_f = 0.36 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, d_6-DMSO): δ [ppm] 2.82 (td, J = 6.8, 2.4 Hz, 4H), 2.21−2.01 (m, 4H), 1.75−1.63 (m, 4H), 1.63 (s, 9H), 1.37 (s, 9H), 1.37−1.24 (m, 12H). ^{13}C NMR (101 MHz, d_6-DMSO): δ [ppm] 198.6, 159.2, 145.1, 135.8, 88.5, 87.9, 45.8, 28.3, 27.0, 26.7, 25.1, 24.7, 24.3, 23.4, 20.9. HRMS (m/z) calculated for [$C_{27}H_{42}N_6O_3Na^+$] 521.3211, found 521.3210.

*tert-Butyl 3-(Adamantan-1-yl)-2,2-diazido-3-oxopropanoate (**2l**).* Following general procedure B (0.515 g of **1l**, 7 h), *tert*-butyl 3-(adamantan-1-yl)-2,2-diazido-3-oxopropanoate **2l** was obtained as a colorless liquid (0.335 g, 0.93 mmol, 50%) after chromatography (CH/EtOAc 98/2). TLC: R_f = 0.48 (CH/EtOAc 90/10, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 2.06−2.00 (m, 3H), 2.00−1.96 (m, 6H), 1.76−1.65 (m, 6H), 1.55 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 201.5, 163.2, 86.7, 83.4, 47.3, 38.6, 36.5, 28.1, 28.0. IR: 2980, 2908, 2853, 2112, 1752, 1719, 1455, 1371, 1236, 1144, 1066, 980, 919, 833, 802, 744, 613, 547 [cm^{-1}]. For HRMS, **2l** was converted to the bistriazole according to general procedure D (0.018 g of **2l**, overnight). *tert*-Butyl 3-(adamantan-1-yl)-2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-3-oxopropanoate was obtained as a colorless liquid (0.027 g, 0.05 mmol, 94%) after chromatography (CH/EtOAc 90/10). TLC: R_f = 0.38 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, d_6-DMSO): δ [ppm] 2.84−2.78 (m, 4H), 2.15−2.01 (m, 13H), 1.74−1.66 (m, 10H), 1.65 (s, 9H), 1.40−1.21 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 198.9, 160.4, 137.0, 131.0, 88.3, 87.3, 49.8, 39.8, 36.8, 28.7, 28.1, 27.7, 26.3, 25.9, 25.4, 24.7, 22.2. HRMS (m/z) calculated for [$C_{33}H_{48}N_6O_3Na^+$] 599.3680, found 599.3680.

*tert-Butyl 2,2-Diazido-3-oxo-3-phenylpropanoate (**2m**).* Following general procedure A (0.949 g of **1m**, 3.5 h, 6.0 equiv of NaN_3, 2.2 equiv of I_2), *tert*-butyl 2,2-diazido-3-oxo-3-phenylpropanoate **2m** was obtained as a colorless liquid (1.209 g, 4.00 mmol, 93%) after chromatography (PE/EtOAc 95/5). Single crystals suitable for crystal structure analysis were obtained by allowing the liquid obtained from chromatography to slowly crystallize.[45] TLC: R_f = 0.46 (PE/EtOAc 95/5, [$KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 8.06−8.00 (m, 2H), 7.64−7.58 (m, 1H), 7.50−7.43 (m, 2H), 1.36 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 186.9, 163.8, 134.5, 132.4, 129.9, 128.8, 86.7, 83.1, 27.7. IR: 3065, 2981, 2936, 2118, 1750, 1704, 1598, 1581, 1476, 1450, 1396, 1372, 1281, 1228, 1185, 1146, 1105, 1050, 1033, 1000, 898, 830, 789, 768, 750, 700, 687, 674, 612, 582, 547, 521, 468, 445 [cm^{-1}]. For HRMS, **2m** was converted to the bistriazole according to general procedure C (0.030 g of **2m**, 0.17 M, 4 h). *tert*-Butyl 3-oxo-3-phenyl-2,2-bis(4-phenyl-1*H*-1,2,3-triazol-1-yl)-propanoate was obtained as a white solid (0.035 g, 0.07 mmol, 70%) after chromatography (PE/EtOAc 100/0 → 70/30). TLC: R_f = 0.62 (PE/EtOAc 70/30, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 8.49 (s, 2H), 7.87−7.81 (m, 4H), 7.75−7.70 (m, 2H), 7.62−7.55 (m, 1H), 7.45−7.39 (m, 6H), 7.37−7.30 (m, 2H), 1.37 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 182.1, 160.1, 148.4, 134.3, 133.4, 129.6, 129.2, 129.1, 129.0, 128.8, 126.0, 120.8, 88.5, 82.4, 27.4. HRMS (m/z) calculated for [$C_{29}H_{26}N_6O_3Na^+$] 529.1959, found 529.1959.

*tert-Butyl 2,2-Diazido-3-oxo-3-(p-tolyl)propanoate (**2n**).* Following general procedure B (0.500 g of **1n**, 2.5 h, 2.5 equiv of I_2), *tert*-butyl 2,2-diazido-3-oxo-3-(*p*-tolyl)propanoate **2n** was obtained as a white solid (0.395 g, 1.25 mmol, 59%) after chromatography (CH/EtOAc 95/5 → 90/10). TLC: R_f = 0.40 (CH/EtOAc 90/10, [UV]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 7.95−7.87 (m, 2H), 7.29−7.21 (m, 2H), 2.42 (s, 3H), 1.38 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 186.4, 163.9, 145.7, 130.0, 129.8, 129.5, 86.6, 83.1, 27.7, 21.9. IR: 2983, 2117, 1745, 1693, 1605, 1459, 1371, 1234, 1145, 996, 901, 829, 793, 726, 602, 544, 474 [cm^{-1}]. For HRMS, **2n** was converted to the bistriazole according to general procedure D (0.020 g of **2n**, 1 h). *tert*-Butyl 2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-3-oxo-3-(*p*-tolyl)propanoate was obtained as a colorless liquid (0.033 g, 0.06 mmol, quant.) after chromatography (CH/EtOAc 90/10 → 80/20). TLC: R_f = 0.32 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 7.68−7.64 (m, 2H), 7.19−7.15 (m, 2H), 2.95−2.85 (m, 4H), 2.38 (s, 3H), 1.99−1.59 (m, 8H), 1.58−1.24 (m, 12H), 1.24 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 182.6, 160.8, 145.9, 144.4, 137.1, 132.7, 129.9, 129.1, 87.1, 85.8, 27.6, 27.3, 26.3, 25.8, 25.2, 24.5, 22.2, 21.8. HRMS (m/z) calculated for [$C_{30}H_{40}N_6O_3Na^+$] 555.3054, found 555.3048.

*tert-Butyl 2,2-Diazido-3-(4-chlorophenyl)-3-oxopropanoate (**2o**).* Following general procedure B (1.000 g of **1o**, 1 h, 2.0 equiv of I_2), *tert*-butyl 2,2-diazido-3-(4-chlorophenyl)-3-oxopropanoate **2o** was obtained as a white solid (0.990 g, 2.94 mmol, 75%) after chromatography (CH/EtOAc 97/3). TLC: R_f = 0.51 (CH/EtOAc 90/10, [UV]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 8.00−7.96 (m, 2H), 7.46−7.43 (m, 2H), 1.39 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 185.9, 163.6, 141.2, 131.3, 130.7, 129.2, 87.0, 83.1, 27.8. IR: 3082, 2982, 2416, 2119, 2103, 1747, 1702, 1585, 1486, 1397, 1372, 1295, 1212, 1146, 1091, 1030, 996, 896, 847, 827, 777, 729, 706, 681, 557, 481, 449 [cm^{-1}]. For HRMS, **2o** was converted to the bistriazole according to general procedure D (0.027 g of **2o**, overnight). *tert*-Butyl 3-(4-chlorophenyl)-2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*]-[1,2,3]triazol-1-yl)-3-oxopropanoate was obtained as a white solid (0.044 g, 0.08 mmol, 99%) after chromatography (CH/EtOAc 90/10 → 80/20). TLC: R_f = 0.34 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 7.74−7.69 (m, 2H), 7.40−7.34 (m, 2H), 2.97−2.82 (m, 4H), 2.46−2.16 (m, 2H), 1.89−1.59 (m, 6H), 1.54−1.29 (m, 12 H), 1.26 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 182.0, 160.5, 146.1, 140.0, 137.1, 133.6, 131.1, 128.8, 87.6, 85.7, 27.6, 27.3, 26.2, 25.8, 25.2, 24.5, 22.1. HRMS (m/z) calculated for [$C_{29}H_{37}N_6O_3ClNa^+$] 575.2508, found 575.2504.

*tert-Butyl 2,2-Diazido-3-(4-methoxyphenyl)-3-oxopropanoate (**2p**).* Following general procedure B (1.000 g of **1p**, 3 h, 2.0 equiv of I_2), *tert*-butyl 2,2-diazido-3-(4-methoxyphenyl)-3-oxopropanoate **2p** was obtained as a white solid (1.025 g, 3.08 mmol, 77%) after chromatography (CH/EtOAc 95/5 → 80/20). TLC: R_f = 0.24 (CH/EtOAc 90/10, [UV]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 8.05−8.00 (m, 2H), 6.96−6.90 (m, 2H), 3.88 (s, 3H), 1.39 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 185.3, 164.6, 164.0, 132.5, 125.0, 114.1, 86.6, 83.2, 55.7, 27.8. IR: 3007, 2980, 2939, 2135, 2116, 1741, 1687, 1590, 1512, 1372, 1318, 1270, 1239, 1145, 1027, 905, 844, 827, 796, 736, 697, 599, 546, 438 [cm^{-1}]. For HRMS, **2p** was converted to the bistriazole according to general procedure D (0.025 g of **2p**, overnight). *tert*-Butyl 2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*]-[1,2,3]triazol-1-yl)-3-(4-methoxyphenyl)-3-oxopropanoate was obtained as a white solid (0.032 g, 0.06 mmol, 73%) after chromatography (CH/EtOAc 90/10 → 70/30). TLC: R_f = 0.22 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 7.76−7.70 (m, 2H), 6.89−6.81 (m, 2H), 3.84 (s, 3H), 2.98−2.82 (m, 4H), 2.57−2.11 (m, 2H), 1.86−1.60 (m, 6H), 1.58−1.30 (m, 12H), 1.26 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 181.6, 163.8, 160.9, 146.0, 137.1, 132.2, 128.0, 113.7, 87.0, 85.9, 55.6, 27.6, 27.4, 26.3, 25.8, 25.2, 24.5, 22.2. HRMS (m/z) calculated for [$C_{30}H_{40}N_6O_4Na^+$] 571.3003, found 571.3008.

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*tert-Butyl 2,2-Diazido-3-(furan-2-yl)-3-oxopropanoate (**2q**).* Following general procedure B (1.000 g of **1q**, 3 h, 2.0 equiv of I_2), *tert*-butyl 2,2-diazido-3-(furan-2-yl)-3-oxopropanoate **2q** was obtained as a white solid (0.889 g, 3.04 mmol, 64%) after chromatography (CH/EtOAc 100/0 → 80/20). TLC: R_f = 0.45 (CH/EtOAc 70/30, [UV]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 7.67 (dd, J = 1.7, 0.7 Hz, 1H), 7.45 (dd, J = 3.7, 0.7 Hz), 6.60 (dd, J = 3.7, 1.7 Hz, 1H), 1.44 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 175.6, 163.1, 148.3, 148.2, 121.9, 113.0, 86.6, 82.4, 27.8. IR: 3140, 2983, 2938, 2115, 1752, 1694, 1566, 1460, 1392, 1372, 1232, 1147, 1025, 941, 886, 857, 825, 766, 591, 545, 440 [cm^{-1}]. For HRMS, **2q** was converted to the bistriazole according to general procedure D (0.034 g of **2q**, overnight). *tert*-Butyl 3-(furan-2-yl)-2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]-triazol-1-yl)-3-oxopropanoate was obtained as a white solid (0.055 g, 0.11 mmol, 90%) after chromatography (CH/EtOAc 90/10 → 70/30). TLC: R_f = 0.21 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 7.47 (dd, J = 1.7, 0.8 Hz, 1H), 7.36 (dd, J = 3.5, 0.8 Hz, 1H), 6.56 (dd, J = 3.6, 1.7 Hz, 1H), 2.97−2.80 (m, 4H), 2.46−2.03 (m, 2H), 1.87−1.58 (m, 6H), 1.55−1.38 (m, 12H), 1.38 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 172.3, 159.6, 150.9, 146.4, 145.8, 136.8, 119.2, 112.8, 86.7, 84.9, 27.6, 27.5, 26.1, 25.8, 25.1, 24.5, 22.1. HRMS (m/z) calculated for [$C_{27}H_{36}N_6O_4Na^+$] 531.2690, found 531.2690.

*(E)-tert-Butyl 2,2-Diazido-3-oxo-5-phenylpent-4-enoate (**2r**).* Following general procedure A (0.201 g of **1r**, 4 h, 6.0 equiv of NaN_3, 2.1 equiv of I_2), (*E*)-*tert*-butyl 2,2-diazido-3-oxo-5-phenylpent-4-enoate **2r** was obtained as a yellowish solid (0.206 g, 0.63 mmol, 77%) after chromatography (PE/EtOAc 90/10). TLC: R_f = 0.74 (PE/EtOAc 90/10, [$KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 7.85 (d, J = 15.8 Hz, 1H), 7.63−7.57 (m, 2H), 7.47−7.39 (m, 3H), 6.94 (d, J = 15.8 Hz, 1H), 1.52 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 186.7, 163.3, 147.7, 134.0, 131.8, 129.3, 129.1, 118.4, 86.7, 83.5, 28.0. IR: 3088, 3074, 3030, 3002, 2982, 2937, 2875, 2109, 1750, 1708, 1607, 1597, 1575, 1497, 1474, 1450, 1474, 1450, 1395, 1370, 1336, 1304, 1275, 1239, 1217, 1181, 1151, 1127, 1049, 1029, 1009, 983, 883, 857, 826, 787, 760, 746, 695, 676, 619, 587, 557, 547, 484, 465, 438 [cm^{-1}]. HRMS (m/z) calculated for [$C_{15}H_{16}N_6O_3Na^+$] 351.1176, found 351.1178.

*tert-Butyl 2,2-Diazido-3-oxohept-6-enoate (**2s**).* Following general procedure B (0.677 g of **1s**, 3 h), *tert*-butyl 2,2-diazido-3-oxohept-6-enoate, **2s** was obtained as a yellowish oil (0.587 g, 2.09 mmol, 61%) after chromatography (CH/Et_2O 100/0 → 90/10). TLC: R_f = 0.58 (PE/EtOAc 95/5, [I_2]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 5.79 (ddt, J = 16.9, 10.2, 6.5 Hz, 1H), 5.07 (dq, J = 17.1, 1.6 Hz, 1H), 5.02 (dq, J = 10.2, 1.4 Hz, 1H), 2.65 (t, J = 7.2 Hz, 2H), 2.41−2.33 (m, 2H), 1.53 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 197.7, 163.1, 136.2, 116.1, 86.9, 83.4, 36.9, 28.0, 27.4. IR: 3081, 2983, 2935, 2113, 1742, 1372, 1237, 1149, 995, 917, 831, 752, 554 [cm^{-1}]. For HRMS, **2s** was converted to the bistriazole according to general procedure C (0.037 g of **2s**, 0.15 M, 3 d). *tert*-Butyl 3-oxo-2,2-bis(4-phenyl-1*H*-1,2,3-triazol-1-yl)hept-6-enoate was obtained as a yellowish oil (0.029 g, 0.06 mmol, 45%) after chromatography (PE/EtOAc 70/30). TLC: R_f = 0.6 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 8.33 (s, 2H), 7.83−7.79 (m, 4H), 7.44−7.38 (m, 4H), 7.36−7.30 (m, 2H), 5.86 (ddt, J = 16.9, 10.2, 6.6 Hz, 1H), 5.12 (dq, J = 17.0, 1.5 Hz, 1H), 5.08−5.03 (m, 1H), 2.89−2.84 (m, 2H), 2.65−2.57 (m, 2H), 1.64 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 191.4, 159.6, 148.3, 136.0, 129.6, 129.0, 128.9, 126.0, 121.0, 116.4, 88.9, 83.5, 38.7, 28.5, 27.8. HRMS (m/z) calculated for [$C_{27}H_{28}N_6O_3Na^+$] 507.2115, found 507.2115.

*tert-Butyl 2,2-Diazido-7-(benzyloxy)-3-oxoheptanoate (**2t**).* Following general procedure A (1.53 g of **1t**, 3.5 h, 10.0 equiv of NaN_3, 2.2 equiv of I_2), *tert*-butyl 2,2-diazido-7-(benzyloxy)-3-oxoheptanoate **2t** was obtained as a colorless liquid (1.27 g, 3.27 mmol, 65%). TLC: R_f = 0.25 (CH/EtOAc 90/10, [UV, $KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 7.37−7.30 (m, 4H), 7.30−7.25 (m, 1H), 4.49 (s, 2H), 3.48 (t, J = 6.1 Hz, 2H), 2.59 (t, J = 7.1 Hz, 2H), 1.78−1.69 (m, 2H), 1.67−1.58 (m, 2H), 1.52 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 198.3, 163.1, 138.6, 128.5, 127.7, 127.7, 86.8, 83.4, 73.1, 69.9, 37.3, 29.1, 27.9, 20.5. IR: 2981, 2937, 2861, 2114, 1741, 1476, 1455, 1397, 1372, 1239, 1150, 1103, 1049, 1028, 999, 940, 831, 735, 697, 612, 547, 467, 442 [cm^{-1}]. For HRMS, **2t** was converted to the bistriazole according to general procedure D ($CDCl_3$, overnight). *tert*-Butyl 7-(benzyloxy)-2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*]-[1,2,3]triazol-1-yl)-3-oxoheptanoate was obtained as a colorless liquid. TLC: R_f = 0.32 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 7.34−7.28 (m, 4H), 7.28−7.22 (m, 1H), 4.48 (s, 2H), 3.51 (t, J = 6.3 Hz, 2H), 3.01−2.90 (m, 2H), 2.90−2.84 (m, 4H), 2.28−2.07 (m, 4H), 2.04−1.93 (m, 2H), 1.78−1.67 (m, 6H), 1.57 (s, 9H), 1.41−1.26 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 192.7, 160.2, 145.9, 138.6, 136.6, 128.4, 127.7, 127.6, 87.7, 86.8, 73.1, 70.1, 41.7, 29.5, 27.7, 27.6, 26.1, 25.7, 25.0, 24.4, 22.7, 22.0. HRMS (m/z) calculated for [$C_{34}H_{48}N_6O_4Na^+$] 627.3629, found 627.3637.

*tert-Butyl 7-acetoxy-2,2-diazido-3-oxoheptanoate (**2u**).* Following general procedure B (0.230 g of **1u**, 3 h,), *tert*-butyl 7-acetoxy-2,2-diazido-3-oxoheptanoate **2u** was obtained as a colorless liquid (0.170 g, 0.50 mmol, 56%) after chromatography (CH/EtOAc 90/10 → 80/20). TLC: R_f = 0.24 (CH/EtOAc 80/20, [UV, $KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 4.05 (t, J = 6.1 Hz, 2H), 2.58 (t, J = 6.9 Hz, 2H), 2.03 (s, 3H), 1.74−1.57 (m, 4H), 1.52 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 198.1, 171.1, 163.1, 86.9, 83.4, 63.9, 37.0, 27.9, 21.0, 20.1. IR: 2981, 2123, 1740, 1459, 1397, 1372, 1238, 1153, 1098, 1043, 833, 753, 556 [cm^{-1}]. For HRMS, **2u** was converted to the bistriazole according to general procedure D ($CDCl_3$, overnight). *tert*-Butyl 7-acetoxy-2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]-triazol-1-yl)-3-oxoheptanoate was obtained as a colorless liquid. **TLC**: R_f = 0.19 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 4.09 (t, J = 6.4 Hz, 2H), 3.00−2.89 (m, 2H), 2.89−2.82 (m, 4H), 2.25−2.07 (m, 4H), 2.02 (s, 3H), 2.00−1.89 (m, 2H), 1.79−1.65 (m, 6H), 1.59 (s, 9H), 1.39−1.17 (m, 12H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 192.5, 171.2, 160.1, 145.9, 136.6, 87.8, 86.7, 64.1, 41.3, 28.3, 27.8, 27.6, 26.1, 25.7, 25.0, 24.4, 22.3, 22.0, 21.1. HRMS (m/z) calculated for [$C_{29}H_{44}N_6O_5Na^+$] 579.3265, found 579.3265.

*tert-Butyl 2,2-Diazido-6-((tert-butyldimethylsilyl)oxy)-3-oxohexanoate (**2v**).* Following general procedure B (0.730 g of **1v**, 3.5 h), *tert*-butyl 2,2-diazido-6-((*tert*-butyldimethylsilyl)oxy)-3-oxohexanoate **2v** was obtained as a colorless liquid (0.660 g, 1.66 mmol, 72%) after chromatography (CH/EtOAc 95/5 → 90/10). TLC: R_f = 0.56 (CH/EtOAc 80/20, [$KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 3.62 (t, J = 6.0 Hz, 2H), 2.65 (t, J = 7.2 Hz, 2H), 1.87−1.76 (m, 2H), 1.53 (s, 9H), 0.88 (s, 9H), 0.04 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 198.5, 163.2, 86.8, 83.5, 61.8, 34.1, 28.0, 26.8, 26.0, 18.4, −5.2. IR: 2955, 2931, 2886, 2858, 2116, 1743, 1472, 1462, 1396, 1372, 1421, 1152, 1101, 1044, 1006, 954, 833, 776, 713, 661, 555, 468, 447 [cm^{-1}]. For HRMS, **2v** was converted to the bistriazole according to general procedure D ($CDCl_3$, overnight). *tert*-Butyl 6-((*tert*-butyldimethylsilyl)oxy)-2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*]-[1,2,3]triazol-1-yl)-3-oxohexanoate was obtained for mass analysis. TLC: R_f = 0.43 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 3.71 (t, J = 6.0 Hz, 2H), 3.04−2.94 (m, 2H), 2.94−2.78 (m, 4H), 2.32−2.03 (m, 6H), 1.75−1.68 (m, 4H), 1.60 (s, 9H), 1.40−1.17 (m, 12H), 0.86 (s, 9H), 0.03 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 193.1, 160.2, 145.9, 136.6, 87.7, 86.8, 62.3, 38.6, 29.0, 27.8, 27.6, 26.1, 26.1, 25.8, 25.1, 24.5, 22.0, 18.4, −5.2. HRMS (m/z) calculated for [$C_{32}H_{54}N_6O_4SiNa^+$] 637.3868, found 637.3839.

*tert-Butyl 2,2,6-Triazido-3-oxohexanoate (**2w**).* Following general procedure B (0.520 g of **1w**, 3 h), *tert*-butyl 2,2,6-triazido-3-oxohexanoate **2w** was obtained as a colorless liquid (0.741 g, 1.86 mmol, 81%) after chromatography (CH/EtOAc 95/5 → 90/10). TLC: R_f = 0.34 (CH/EtOAc 80/20, [$KMnO_4$]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 3.34 (t, J = 6.5 Hz, 2H), 2.66 (t, J = 6.9 Hz, 2H), 1.94−1.86 (m, 2H), 1.54 (s, 9H). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 197.8, 163.0, 87.1, 83.4, 50.4, 34.4, 27.9, 22.9. IR: 2983, 2932, 2112, 2098, 1742, 1459, 1397, 1372, 1353, 1239, 1151, 1077, 1031, 956, 883, 832, 749, 626, 556, 468, 444 [cm^{-1}]. For HRMS, **2w** was converted to the bistriazole according to general procedure D (overnight). *tert*-Butyl 2,2,6-tris(4,5,6,7,8,9-hexahydro-1*H*-cycloocta-[*d*][1,2,3]triazol-1-yl)-3-oxohexanoate was obtained for mass analysis. TLC: R_f = 0.02 (CH/EtOAc 80/20, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 4.36 (t, J = 7.0 Hz, 2H), 2.99−2.89 (m, 2H),

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2.89−2.81 (m, 6H), 2.81−2.72 (m, 2H), 2.49−2.37 (m, 2H), 2.25−2.06 (m, 4H), 1.87−1.76 (m, 2H), 1.76−1.64 (m, 6H), 1.56 (s, 9H), 1.51−1.27 (m, 16H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 192.4, 159.8, 146.0, 144.9, 136.6, 133.0, 88.3, 86.5, 46.9, 38.3, 28.4, 27.7, 27.6, 26.6, 26.1, 26.1, 26.0, 25.7, 25.0, 24.9, 24.6, 24.4, 22.0, 21.8. HRMS (m/z) calculated for $[C_{34}H_{52}N_9O_3^+]$ 634.4188, found 634.4188.

*tert-Butyl 2,2-Diazido-5-hydroxy-5-methyl-3-oxohexanoate (**2x**).* Following general procedure A (0.200 g of **1x**, 4 h, 6.0 equiv of NaN_3, 2.2 equiv of I_2), *tert*-butyl 2,2-diazido-5-hydroxy-5-methyl-3-oxohexanoate **2x** was obtained as a colorless liquid (0.214 g, 0.72 mmol, 78%) after chromatography (PE/EtOAc 90/10 → 70/30). TLC: R_f = 0.38 (PE/EtOAc 80/20, [$KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 3.05 (s, 1H), 2.75 (s, 2H), 1.54 (s, 9H), 1.29 (s, 6H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 199.5, 162.8, 87.3, 83.5, 69.9, 48.9, 29.4, 28.0. IR: 3560, 3436, 2980, 2937, 2116, 1741, 1459, 1372, 1238, 1148, 1053, 831, 749, 545, 467 [cm^{-1}]. HRMS (m/z) calculated for $[C_{11}H_{18}N_6O_4Na^+]$ 321.1282, found 321.1282.

*tert-Butyl 2,2-Diazido-5-hydroxy-6-methyl-3-oxoheptanoate (**2y**).* Following general procedure A (0.200 g of **1y**, 4 h, 6.0 equiv of NaN_3, 2.2 equiv of I_2), *tert*-butyl 2,2-diazido-5-hydroxy-6-methyl-3-oxoheptanoate **2y** was obtained as a colorless liquid (0.207 g, 0.66 mmol, 76%) after chromatography (PE/EtOAc 90/10 → 80/20). TLC: R_f = 0.61 (PE/EtOAc 80/20, [CAM]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 3.93−3.83 (m, 1H), 2.75−2.61 (m, 2H), 2.39 (s, 1H), 1.78−1.65 (m, 1H), 1.54 (s, 9H), 0.96 (d, J = 6.8 Hz, 3H), 0.95 (d, J = 6.8 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 199.3, 162.9, 87.2, 83.6, 72.0, 42.0, 33.3, 27.9, 18.5, 17.7. IR: 3569, 3467, 2966, 2936, 2911, 2877, 2115, 1741, 1626, 1460, 1396, 1372, 1239, 1150, 1051, 994, 960, 831, 750, 705, 546, 468, 435 [cm^{-1}]. For HRMS, **2y** was converted to the bistriazole according to general procedure D (0.033 g of **2y**, overnight). *tert*-Butyl 2,2-bis(4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazol-1-yl)-5-hydroxy-6-methyl-3-oxoheptanoate was obtained as a colorless liquid. ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 4.23−4.15 (m, 1H), 3.23−3.00 (m, 2H), 2.94−2.81 (m, 4H), 2.31−2.09 (m, 4H), 1.82−1.67 (m, 5H), 1.61 (s, 9H), 1.58−1.49 (m, 1H), 1.41−1.28 (m, 12H), 0.97 (d, J = 6.6 Hz, 3H), 0.96 (d, J = 6.6 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 193.8, 159.8, 146.1, 136.7, 88.3, 86.7, 73.1, 45.9, 33.6, 27.8, 27.6, 26.1, 25.8, 25.1, 24.5, 22.0, 18.5, 17.4. HRMS (m/z) calculated for $[C_{28}H_{44}N_6O_4Na^+]$ 551.3316, found 551.3315.

*(S)-tert-Butyl 2,2-Diazido-4-((tert-butoxycarbonyl)amino)-3-oxopentanoate (**2z**).* Following general procedure A (0.500 g of **1z**, 0.06 M, DMSO/H_2O 5/1, 5 h, 10.0 equiv of NaN_3, 2.2 equiv of I_2), (*S*)-*tert*-butyl 2,2-diazido-4-((*tert*-butoxycarbonyl)amino)-3-oxopentanoate **2z** was obtained as a white solid (0.453 g, 1.23 mmol, 70%, 96% ee) after chromatography (PE/EtOAc 90/10). TLC: R_f = 0.50 (PE/EtOAc 85/15, [UV]). ^{1}H NMR (600 MHz, $CDCl_3$): δ [ppm] 5.01−4.91 (m, 1H), 4.79−4.67 (m, 1H), 1.53 (s, 9H), 1.43 (s, 9H), 1.35 (d, J = 6.9 Hz). ^{13}C NMR (151 MHz, $CDCl_3$): δ [ppm] 199.4, 162.6, 154.7, 87.2, 82.4, 80.4, 52.3, 28.4, 27.9, 18.6. IR: 2981, 2936, 2123, 1737, 1710, 1515, 1455, 1370, 1239, 1152, 1044, 951, 833, 784, 756, 701, 609, 547, 464 [cm^{-1}]. HRMS (m/z) calculated for $[C_{14}H_{23}N_7O_5Na^+]$ 392.1653, found 392.1645.

*(S)-tert-Butyl 2,2-Diazido-4-((tert-butoxycarbonyl)amino)-6-methyl-3-oxoheptanoate (**2aa**).* Following general procedure A (0.360 g of **1aa**, 0.04 M, DMSO/H_2O 5/1, 3 h, 10.0 equiv of NaN_3, 2.2 equiv of I_2), (*S*)-*tert*-butyl 2,2-diazido-4-((*tert*-butoxycarbonyl)-amino)-6-methyl-3-oxoheptanoate **2aa** was obtained as a colorless oil (0.354 g, 0.96 mmol, 79%, 93% ee) after chromatography (PE/EtOAc 90/10). TLC: R_f = 0.50 (PE/EtOAc 85/15, [UV]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 4.84−4.66 (m, 2H), 1.77−1.61 (m, 2H), 1.53 (s, 9H), 1.43 (s, 9H), 1.36−1.26 (m, 1H), 0.98 (d, J = 6.3 Hz, 3H), 0.94 (d, J = 6.5 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 199.6, 162.6, 155.2, 87.1, 82.4, 80.3, 55.1, 41.6, 28.4, 27.9, 25.1, 23.5, 21.3. IR: 2962, 2935, 2873, 2122, 1745, 1709, 1498, 1393, 1240, 1151, 1048, 1023, 831, 547 [cm^{-1}]. HRMS (m/z) calculated for $[C_{17}H_{29}N_7O_5Na^+]$ 434.2122, found 434.2130.

*2,2-Diazido-N,N-dimethyl-3-oxobutanamide (**2ab**).* Following general procedure A (0.200 g of **1ab**, 3 h, 10.0 equiv of NaN_3, 2.5 equiv of I_2), 2,2-diazido-*N*,*N*-dimethyl-3-oxobutanamide **2ab** was obtained as a colorless liquid (0.162 g, 0.77 mmol, 50%) after chromatography (PE/EtOAc 50/50 → 20/80). TLC: R_f = 0.62 (PE/EtOAc 50/50, [$KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 3.01 (s, 3H), 2.97 (s, 3H), 2.28 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 196.6, 162.7, 85.7, 37.7, 37.5, 24.9; IR: 2937, 2110, 1739, 1722, 1663, 1495, 1459, 1396, 1358, 1212, 1155, 1056, 1003, 999, 961, 942, 884, 773, 719, 670, 650, 585, 557, 536, 466, 455, 419 [cm^{-1}]. For HRMS, **2ab** was converted to the bistriazole according to general procedure C (0.030 g of **2ab**, 24 h). *N*,*N*-Dimethyl-3-oxo-2,2-bis(4-phenyl-1*H*-1,2,3-triazol-1-yl)butanamide was obtained as a white solid (0.037 g, 0.09 mmol, 63%) after chromatography (PE/EtOAc 100/0 → 0/100). TLC: R_f = 0.15 (PE/EtOAc 80/20, [$KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 8.32 (s, 2H), 7.82−7.79 (m, 4H), 7.42−7.37 (m, 4H), 7.35−7.29 (m, 2H), 3.22 (s, 3H), 2.63 (s, 3H), 2.56 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 191.4, 159.5, 148.4, 129.5, 129.0, 128.9, 126.0, 121.4, 84.7, 38.4, 37.8, 26.7. HRMS (m/z) calculated for $[C_{22}H_{21}N_7O_2Na^+]$ 438.1649, found 438.1636.

*3,3-Diazido-5,5-dimethylhexane-2,4-dione (**2ac**).* Following general procedure A (0.500 g of **1ac**, 3 h, 10.0 equiv of NaN_3, 2.5 equiv of I_2), 3,3-diazido-5,5-dimethylhexane-2,4-dione **2ac** was obtained as a colorless liquid (0.562 g, 2.51 mmol, 73%) after chromatography (PE/EtOAc 95/5). TLC: R_f = 0.61 (PE/EtOAc 90/10, [$KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 2.28 (s, 3H), 1.26 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 204.6, 197.1, 86.7, 45.0, 27.2, 25.2. IR: 2974, 2937, 2914, 2876, 2114, 1740, 1716, 1696, 1481, 1396, 1360, 1216, 1178, 1095, 1055, 1038, 996, 941, 880, 796, 767, 724, 698, 671, 645, 606, 577, 540, 460 [cm^{-1}]. For HRMS, **2ac** was converted to the bistriazole according to general procedure C (0.030 g of **2ac**, 24 h). 5,5-Dimethyl-3,3-bis(4-phenyl-1*H*-1,2,3-triazol-1-yl)hexane-2,4-dione was obtained as a white solid (0.041 g, 0.10 mmol, 72%) after chromatography (PE/EtOAc 100/0 → 70/30). TLC: R_f = 0.57 (PE/EtOAc 80/20, [$KMnO_4$]). ^{1}H NMR (400 MHz, $CDCl_3$): δ [ppm] 8.39 (s, 2H), 7.84−7.81 (m, 4H), 7.43−7.39 (m, 4H), 7.36−7.31 (m, 2H), 2.54 (s, 3H), 1.22 (s, 9H). ^{13}C NMR (101 MHz, $CDCl_3$): δ [ppm] 200.5, 191.2, 148.2, 129.5, 129.0, 128.9, 126.0, 121.1, 88.7, 47.6, 29.0, 28.4. HRMS (m/z) calculated for $[C_{24}H_{24}N_6O_2Na^+]$ 451.1853, found 451.1848.

*Competition Experiment. tert-Butyl-3-oxobutanoate (**1g**).* (0.100 g, 0.61 mmol, 1.0 equiv) and *tert*-butyl 2-methyl-3-oxobutanoate (**3**) (0.106 g, 0.61 mmol, 1.0 equiv) were dissolved in a 2:1 mixture of DMSO (4 mL) and water (2 mL). Sodium azide (0.080 g, 1.23 mmol, 2.0 equiv) and iodine (0.342 g, 1.35 mmol, 2.2 equiv) were added, and the reaction mixture was stirred for 5 h at room temperature. A saturated aqueous solution of sodium thiosulfate was added, and the mixture was extracted with ethyl acetate. The combined organic phases were dried over magnesium sulfate and evaporated *in vacuo*. A sample of the residue was directly submitted to ^{1}H NMR spectroscopy. The ratio of the obtained products was determined by integration of the signals of the acetyl groups.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.joc.5b02328.

Crystallographic data (CIF)

NMR spectra, TGA−DSC measurements, crystallographic data, and HPLC traces (PDF)

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Notes

The authors declare no competing financial interest.

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