Acid Promoted Metal Free Synthesis of Trizole-Fused Heterocycles via Intramolecular [3+2] Cycloaddition

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Supporting Information

General information

All chemicals and solvents were of analytical grade and were used without further purifications. All reactions were conducted in oven-dried (135 °C) glassware under an inert atmosphere of dry nitrogen. The progress of reactions was monitored by silica gel thin layer chromatography (TLC) plates (mesh size 60Å, MERCK). Products were purified by flash column chromatography (FCC) on 40-63 mesh silica gel 60 (MERCK). 

1H and 13C NMR were recorded on Bruker AV-400(400 MHz) or JEOL JNM-ECP500 spectrometer (400MHz or 500MHz for 1H NMR, 100MHz or 126 MHz for 13C NMR). Chemical shifts are reported as δ values in ppm and calibrated by residual solvent peak or tetramethylsilane (δ 0 for 1H NMR). Abbreviations are following: s (singlet), d (doublet), t (triplet), q (quartet), br (broad peak), m (complex multiplet). Mass spectra were measured on HP-1100 LC-MS spectrometer. X-ray crystallography was performed on Rigaku R-AXIS RAPID/S imaging plate diffractometer. Flash column chromatography was performed by MERCK Silica gel 60. The progress of reactions was monitored by silica gel thin layer chromatography plates (MERCK TLC Silicagel 60 F254). Phosphomolybdic acid ethanol solution, ninhydrin-acetic acid butanol solution and anisaldehyde-acetic acid-sulfuric acid ethanol solution were used as TLC stain.

Experimental Procedure of Azido-Propargyl Alcohol

To a stirred solution of corresponding propargyl alcohol and TsCl in dichloromethane
was triethylamine added under nitrogen atmosphere. After 2 h, the mixture was
diluted with ethyl acetate and was washed with water and brine. Drying collected
organic layer over MgSO$_4$ followed by silica gel column chromatography gave
tosylate compound.

To a stirred solution of tosylate compound in dry THF under an atmosphere of
nitrogen was added dropwise $n$-BuLi at -78 °C and the mixture was stirred for 10 min.
Benzaldehyde was then added at same temperature. After 4h, the reaction was
quenched with water. The mixture was diluted with ethyl acetate and was washed with
water and brine. Drying collected organic layer over MgSO$_4$. The crude product can
be used to the next step without further purification.

To a stirred solution of benzyl alcohols in DMF was added sodium azide at room
temperature and the reaction mixture was heated to 50 °C. After 20 min, the reaction
mixture was diluted with ether and was washed with water and brine. Drying collected
organic layer over MgSO$_4$ followed by silica gel column chromatography
gave azide as colorless oil.

7-azido-1,1-diphenylhept-2-yn-1-ol(1a)

$$\text{Ph}$$
$$\text{OH}$$
$$\text{N}_3$$

The reaction with tosylate compound(0.255 g, 1.07 mmol), $n$-BuLi (1.55 M in hexane,
0.729 mL, 1.15 mmol) and ketone (0.15 g, 0.823 mmol) in THF (8 mL) followed by
followed by collected the organic layer under vacuum affording the product 0.45 g.
[silica gel purification (ethyl acetate / hexane = 1 / 8 to 1/3)].

Colorless solid; R$_f$ value 0.28(ethyl acetate/hexane = 1/3); $^1$H NMR(500 MHz, CDCl$_3$)
$\delta$ 7.78(d, 2H, $J = 8.0$ Hz), 7.60–7.57(m, 4H), 7.38–7.31(m, 6H), 7.28–7.25(m, 2H),
4.06(t, 2H, $J = 6.5$ Hz), 2.92(s, 1H, OH), 2.44(s, 3H), 2.34(t, 2H, $J = 7.0$ Hz), 1.82(tt,
2H, $J = 6.5$, 6.5 Hz), 1.63(tt, 2H, $J = 6.5$, 7.0 Hz); $^{13}$C NMR(126 MHz, CDCl$_3$) $\delta$
145.4, 144.8, 132.9, 129.9, 128.2, 127.8, 127.5, 125.9, 86.9, 83.9, 74.4, 69.9, 28.0,
24.3, 21.6, 18.3; HRMS (ESI) calcd for C$_{26}$H$_{26}$O$_4$SNa [M+Na]$^+$457.14495, found 457.14440.

Then the crude benzyl alcohol with sodium azide (83.47 mg, 1.28 mmol) in DMF (20
ml) followed by silica gel column chromatography (ethyl acetate / hexane = 1/10 to
1/5) gave azide 1a (0.108 g, 43%) as a colorless oil.

Colorless oil; R$_f$ value 0.47(ethyl acetate/hexane = 1/5); $^1$H NMR(500 MHz, CDCl$_3$) $\delta$
7.60(m, 4H), 7.33(dd, 4H, $J = 6.5$, 6.5 Hz), 7.27(m, 2H), 3.31(t, 2H, $J = 6.5$ Hz),
2.76(s, 1H, OH), 2.40(t, 2H, $J = 7.0$ Hz), 1.66–1.76(m, 4H); $^{13}$C NMR(126 MHz, CDCl$_3$) $\delta$
145.3, 128.2, 127.6, 125.9, 87.2, 83.7, 74.4, 50.9, 28.0, 25.6, 18.5; HRMS (ESI) calcd for C$_{19}$H$_{19}$N$_3$ONa [M+Na]$^+$328.1426, found 328.1424.
6-azido-1,1-diphenylhex-2-yn-1-ol (1b)

\[
\begin{align*}
\text{Ph} & \quad \text{OH} \\
\text{Ph} & \quad \equiv & \quad \cdots & \quad \text{N}_3
\end{align*}
\]

(1b)

The reaction with tosylate (0.543 g, 2.15 mmol), \(n\)-BuLi (1.58 M in hexane, 1.46 mL, 2.30 mmol) and ketone (0.28 g, 1.54 mmol) in THF (15 mL) followed by collected the organic layer under vacuum affording the product 2.2 g. [silica gel purification (ethyl acetate / hexane = 1 / 8 to 1/4)].

Colorless oil; \(R_f\) value 0.25(ethyl acetate/hexane = 1/4); IR (NaCl, neat) \(\nu_{\max}\) 3502, 3060, 3029, 2958, 1598, 1491, 1449, 1360, 1175 cm\(^{-1}\); \(^1\)H NMR(500 MHz, CDCl\(_3\)) \(\delta\) 7.75(d, 2H, \(J = 7.5\) Hz), 7.53(m, 4H), 7.23–7.32(m, 8H), 4.15(t, 2H, \(J = 6.0\) Hz), 2.76(s, 1H), 2.43(t, 2H, \(J = 6.5\) Hz), 2.39(s, 3H), 1.90(tt, 2H, \(J = 6.5, 6.0\) Hz); \(^{13}\)C NMR(126 MHz, CDCl\(_3\)) \(\delta\) 145.1, 144.8, 132.8, 129.9, 128.2, 127.9, 127.6, 125.9, 85.5, 84.4, 74.3, 68.8, 27.7, 21.6, 15.2; LRMS (EI) 420(M\(^+\), 0.8%), 403(5), 343(100), 220(53), 105(71); HRMS (EI) calcd for C\(_{25}\)H\(_{24}\)O\(_4\)S (M\(^+\)) 420.1395, found 420.1397.

Then the crude benzyl alcohol with sodium azide (0.124 g, 1.9 mmol) in DMF (5 ml) followed by silica gel column chromatography (ethyl acetate / hexane = 1/10 to 1/5) gave azide \(1b\) (0.32 g, 70%) as a colorless oil.

Colorless oil; \(R_f\) value 0.50(ethyl acetate/hexane = 1/4); IR (NaCl, neat) \(\nu_{\max}\) 3426, 2933, 2099, 1490, 1449 cm\(^{-1}\); \(^1\)H NMR(500 MHz, CDCl\(_3\)) \(\delta\) 7.59(m, 4H), 7.31(m, 4H), 7.27(m, 2H), 3.43(t, 2H, \(J = 6.5\) Hz), 2.75(s, 1H), 2.48(t, 2H, \(J = 7.0\) Hz), 1.85(tt, 2H, \(J = 7.0, 6.5\) Hz); \(^{13}\)C NMR(126 MHz, CDCl\(_3\)) \(\delta\) 145.2, 128.2, 127.6, 125.9, 85.4, 74.3, 68.8, 27.7, 21.6, 15.2; LRMS (EI) 292(M\(^+\), 0.8%), 403(5), 343(100), 220(53), 105(71); HRMS (CI) calcd for C\(_{18}\)H\(_{18}\)N\(_3\)O [M+H]\(^+\) 292.1450, found 292.1455.

8-azido-1,1-diphenyloct-2-yn-1-ol (1c)

\[
\begin{align*}
\text{Ph} & \quad \text{OH} \\
\text{Ph} & \quad \equiv & \quad \cdots & \quad \text{N}_3
\end{align*}
\]

(1c)

To a stirred solution of hept-6-yn-1-ol (700.0 mg, 6.05 mmol) and TsCl (1.27 mg, 6.66 mmol) in dichloromethane (6 ml) was added triethylamine (1.01 mL, 7.26 mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO\(_4\) followed by silica gel column chromatography (ethyl acetate/ Petroleum ether = 1/25) gave tosylate compound \(15c\) (1.15 g, 71.7%) as a colorless oil.

Colorless oil; \(R_f\) value 0.63(ethyl acetate/Petroleum ether = 1/5); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.79 (d, 2H, \(J = 8.4\) Hz), 7.34 (d, 2H, \(J = 8.0\) Hz), 4.02 (t, 2H, \(J = 6.4\) Hz), 2.45 (s, 3H), 2.14 (td, 2H, \(J = 6.8, 2.4\) Hz), 1.92 (t, 1H, \(J = 2.4\) Hz), 1.66 (tt, 2H, \(J = 6.8, 6.8\) Hz), 1.51-1.38 (m, 4H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 144.7, 133.1, 129.8,
The reaction with tosylate 15c (0.25 g, 1.37 mmol), n-BuLi (1.58 M in hexane, 1.20 mL, 1.92 mmol) and ketone (0.475 g, 1.78 mmol) in THF (15 mL) followed by collected the organic layer under vacuum affording the product 0.581 g.

Then the crude benzyl alcohol with sodium azide (0.101 g, 1.56 mmol) in DMF (5 ml) followed by silica gel column chromatography (ethyl acetate/petroleum ether= 20/1 to 10/1) gave azide 1c (0.331 g, 80%) as a colorless oil.

Rf value 0.475(ethyl acetate/petroleum ether = 1/5); 1H NMR (400 MHz, CDCl3) δ 7.60 (d, 4H, J = 7.2 Hz), 7.34 (dd, 4H, J = 7.2, 7.6 Hz), 7.27–7.24 (m, 2H), 3.26 (t, 2H, J = 6.4 Hz), 2.76 (s, 1H), 2.37 (t, 2H, J = 7.0 Hz), 1.64–1.59 (m, 4H), 1.55–1.48 (m, 2H); 13C NMR (100 MHz, CDCl3) δ 145.4, 128.1, 127.5, 125.9, 87.6, 83.5, 74.4, 51.2, 28.3, 28.0, 25.9, 18.7; HRMS (ESI) calcd for C20H22N3O [M+H]+ 320.1763, found 320.1763.

9-azido-1,1-diphenylnon-2-yn-1-ol (1d)

To a stirred solution of oct-7-yn-1-ol (0.4g, 3.46mmol) and TsCl (0.725g, 3.80mmol) in dichloromethane (30 ml) was added triethylamine (0.577mL, 420mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO4 followed by silica gel column chromatography (ethyl acetate/ Petroleum ether= 1/40 to 1/30) gave tosylate compound 15d (0.721 g, 78%) as a colorless oil.

Colorless oil; Rf value 0.55(ethyl acetate/ Petroleum ether= 1/5); 1H NMR (400 MHz, CDCl3) δ 7.79 (d, 2H, J = 8.4 Hz), 7.34 (d, 2H, J = 8.0 Hz), 4.02 (t, 2H, J = 6.4 Hz), 2.45 (s, 3H), 2.14 (td, 2H, J = 6.8, 2.4 Hz), 1.92 (t, 1H, J = 2.4 Hz), 1.68-1.63 (m, 2H), 1.50-1.44 (m, 2H), 1.38-1.32 (m, 4H); 13C NMR (100 MHz, CDCl3) δ 145.4, 144.6, 128.0, 125.8, 87.3, 74.3, 70.2, 28.12, 27.6, 24.5, 21.5, 18.5; HRMS (ESI) calcd for C13H12O3S [M+H]+ 281.1211, found 281.1216.

The reaction with tosylate 15d (1.00 g, 2.74 mmol), n-BuLi (1.60 M in hexane, 2.40 mL, 3.84 mmol) and ketone (0.50 g, 1.78 mmol) in THF (27 mL) followed by collected the organic layer under vacuum affording the product 1.20 g.

Then the crude benzyl alcohol with sodium azide (0.200 g, 3.11 mmol) in DMF (5 ml)
followed by silica gel column chromatography (ethyl acetate/ petroleum ether= 20/1 to 10/1) gave azide 1d (0.825 g, 95%) as a colorless oil.

Rf value 0.475(ethyl acetate/ petroleum ether= 1/5); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.60 (d, 4H, $J$ = 7.2 Hz ), 7.32 (dd, 4H, $J$ = 7.2, 7.6 Hz), 7.27 – 7.23 (m, 2H), 3.25 (t, 2H, $J$ = 6.8 Hz), 2.79 (s, 1H), 2.36 (t, 2H, $J$ = 6.8 Hz), 1.64 – 1.56 (m, 4H), 1.50 – 1.36 (m, 4H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 145.5, 128.1, 127.5, 125.9, 87.9, 83.3, 74.4, 51.3, 28.7, 28.32, 28.27, 26.1, 18.8; HRMS (ESI) calcd for C$_{21}$H$_{24}$N$_3$O [M+H]$^+$ 334.1919, found 334.1914.

9-azido-1,1-diphenylnon-2-yn-1-ol (1e)

![1e](image)

To a stirred solution of oct-7-yn-1-ol (0.3 g, 1.71 mmol) and TsCl (0.360 g, 1.88 mmol) in dichloromethane (10 ml) was added triethylamine (0.285 mL, 2.05 mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO$_4$ followed by silica gel column chromatography (ethyl acetate / Petroleum ether = 1/100 to 1/60) gave tosylate compound 15e (0.525 g, 95.1%) as a colorless oil.

Colorless oil; Rf value 0.47(ethyl acetate/ Petroleum ether= 1/10); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.79 (d, 2H, $J$ = 8.4 Hz), 7.34 (d, 2H, $J$ = 8.4 Hz), 4.01 (t, 2H, $J$ = 6.8 Hz), 2.45 (s, 3H), 2.17 (td, 2H, $J$ = 7.2, 2.4 Hz), 1.94 (t, 1H, $J$ = 2.4 Hz), 1.66-1.59 (m, 2H), 1.54-1.46 (m, 2H), 1.37-1.32 (m, 2H), 1.30-1.23 (m, 8H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 144.6, 133.2, 129.8, 127.8, 84.7, 70.6, 68.1, 29.2, 28.9, 28.8, 28.6, 28.4, 25.3, 21.6, 18.3; HRMS (ESI) calcd for C$_{18}$H$_{27}$O$_5$S [M+H]$^+$ 323.1685, found 323.1685.

The reaction with tosylate 15e (0.433g, 1.34 mmol), n-BuLi (1.60 M in hexane, 0.900 mL, 1.44 mmol) and ketone (0.188 g, 1.03 mmol) in THF (10 mL) followed by collected the organic layer under vacuum affording the product 0.470 g.

Then the crude benzyl alcohol with sodium azide (0.073g, 1.12 mmol) in DMF (5 ml) followed by silica gel column chromatography (ethyl acetate/petroleum ether = 20/1 to 10/1) gave azide 1e (0.234 g, 67%) as a colorless oil.

Rf value 0.475(ethyl acetate/petroleum ether = 1/5); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.60 (d, 4H, $J$ = 7.2 Hz ), 7.32 (dd, 4H, $J$ = 7.2, 8.0 Hz), 7.27–7.23 (m, 2H), 3.25 (t, 2H, $J$ = 6.8 Hz), 2.74 (s, 1H), 2.34 (t, 2H, $J$ = 6.8 Hz), 1.62–1.55 (m, 6H), 1.44–1.30 (m, 8H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 145.5, 128.1, 127.4, 126.0, 88.2, 83.1, 74.4,
51.4, 29.3, 29.0, 28.9, 28.82, 28.78, 28.5, 26.7, 18.9; HRMS (ESI) calcd for C_{24}H_{38}N_3O [M+H]^+ 376.2389, found 376.2389.

8-azido-1,1-diphenyloct-2-yn-1-ol (1f)

To a stirred solution of 2-(prop-2-yn-1-yl)propane-1,3-diol (120.0 mg, 1.05 mmol) and TsCl (561.2 mg, 2.94 mmol) in dichloromethane (10 ml) was added triethylamine (0.511 mL, 3.68 mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO_4 followed by silica gel column chromatography (ethyl acetate/ Petroleum ether= 1/40 to 1/15) gave tosylate compound (0.373g, 84%) as a colorless oil.

Colorless oil; R_f value 0.45(ethyl acetate/petroleum ether = 1/10); ^1H NMR (400 MHz, CDCl_3) δ 7.75 (d, 2H, J = 8.0 Hz), 7.36 (d, 2H, J = 8.0 Hz), 4.02 (d, 4H, J = 2.8Hz), 2.46 (s, 6H), 2.24 (s, 3H), 1.86 (s, 1H); ^13C NMR (100 MHz, CDCl_3) δ 145.2, 132.2, 130.0, 127.9, 79.1, 71.1, 67.9, 37.3, 21.7, 17.2; HRMS (ESI) calcd for C_{20}H_{23}O,S [M+H]^+ 423.0936, found 423.0936.

The reaction with tosylate 15f (0.334 g, 0.790 mmol), n-BuLi (1.60 M in hexane, 0.576 mL, 0.922 mmol) and ketone (0.120 g, 0.659 mmol) in THF (8 mL) followed by collected the organic layer under vacuum affording the product 0.370 g.

Then the crude benzyl alcohol with sodium azide (0.103 g, 1.59 mmol) in DMF (5 ml) followed by silica gel column chromatography (ethyl acetate/petroleum ether = 20/1 to 10/1) gave azide 1f (0.148 g, 81%) as a colorless oil.

R_f value 0.45(ethyl acetate/petroleum ether = 1/5); ^1H NMR (400 MHz, CDCl_3) δ 7.57 (d, 4H, J = 6.4 Hz ), 7.34 (dd, 4H, J = 7.2, 7.6 Hz), 7.28 (d, 2H, J = 6.4 Hz), 3.44 (d, 4H, J = 6.0 Hz), 2.74 (br, 1H), 2.49 (d, 2H, J = 6.8 Hz), 2.09–2.03 (m, 1H); ^13C NMR (100 MHz, CDCl_3) δ 145.0, 128.3, 127.7, 125.9, 85.9, 83.8, 74.5, 52.0, 38.2, 19.6; HRMS (ESI) calcd for C_{19}H_{19}N_6O [M+H]^+ 347.1620, found 347.1623.

4-(2-azidoethoxy)-1,1-diphenylbut-2-yn-1-ol (3a)

To a stirred solution of 2-(prop-2-yn-1-yloxy)ethanol (0.7 g, 6.99 mmol) and TsCl (1.60 g, 8.39 mmol) in dichloromethane (10 ml) was added triethylamine (3.49 mL,
24.47 mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO₄ followed by silica gel column chromatography (ethyl acetate/ Petrol ether= 1/20 to 1/10 to 1/2) gave tosylate compound 16a (1.62 g, 91%) as a colorless oil.

Colorless oil; Rf value 0.3(ethyl acetate/ Petroleum ether= 1/5); ¹H NMR (400 MHz, CDCl₃) δ 7.80(d, 2H, J = 8.0 Hz), 7.34 (d, 2H, J = 8.0 Hz), 4.19 (t, 2H, J = 4.8 Hz), 4.11 (s, 2H), 3.72 (t, 2H, J = 4.4 Hz), 2.44 (s, 3H), 2.42 (s, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 144.8, 132.9, 129.8, 127.9, 78.9, 75.0, 68.8, 67.1, 58.3, 21.6; HRMS (ESI) calcd for C₁₂H₁₄O₄S [M]+ 254.0613, found 254.0610.

The reaction with tosylate 16a (1.09 g, 4.28mmol), n-BuLi (1.60 M in hexane, 2.88ml, 4.61mmol) and ketone (0.6g, 3.29mmol) in THF (33 mL) followed by collected the organic layer under vacuum affording the product 1.2 g.

Then the crude benzyl alcohol with sodium azide (0.214g, 3.3 mmol) in DMF (5 ml) followed by silica gel column chromatography (ethyl acetate/ petroleum ether= 20/1 to 10/1) gave azide 3a (0.625 g, 74 %) as a colorless oil.

Rf value 0.35(ethyl acetate/ petroleum ether= 1/5); ¹H NMR (400 MHz, CDCl₃) δ 7.59 (d, 4H, J = 7.6 Hz ), 7.34 (dd, 4H, J = 7.2, 7.6 Hz), 7.27 (d, 2H, J = 7.2 Hz), 4.38 (s, 2H), 3.73 (t, 2H, J = 4.8 Hz), 3.42 (t, 2H, J = 4.8 Hz), 2.82 (br, 1H); ¹³C NMR (100 MHz, CDCl₃) δ 144.6, 128.3, 127.8, 125.9, 89.5, 82.8, 74.4, 68.5, 58.8, 50.6; HRMS (ESI) calcd for C₁₈H₁₇N₃O₂Na [M+Na]+ 330.1218, found 330.1217.

4-(3-azidopropoxy)-1,1-diphenylbut-2-yn-1-ol (3b)

To a stirred solution of 3-(prop-2-yn-1-yloxy)propan-1-ol (0.8 g, 7.01 mmol) and TsCl (1.60 g, 8.41 mmol) in dichloromethane (10 ml) was added triethylamine (3.50 mL, 24.53 mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO₄ followed by silica gel column chromatography (ethyl acetate/ Petroleum ether= 1/20 to 1/10 to 1/2) gave tosylate compound 16b (1.57 g, 83%) as a colorless oil.

Colorless oil; Rf value 0.3(ethyl acetate/ Petroleum ether= 1/5); ¹H NMR (400 MHz, CDCl₃) δ 7.79(d, 2H , J = 8.4 Hz), 7.35 (d, 2H, J = 8.0 Hz), 4.13 (t, 2H, J = 6.4 Hz), 4.03 (s, 2H), 3.53 (t, 2H, J = 6.0 Hz), 2.43 (s, 3H), 2.40 (s, 1H), 1.93 (tt, 2H, J = 6.0, 6.0 Hz); ¹³C NMR (100 MHz, CDCl₃) δ144.7, 133.0, 129.8, 127.9, 79.4, 74.5, 67.5, 65.4, 58.2, 29.1, 21.6; HRMS (ESI) calcd for C₁₃H₁₇O₄S [M+H]+ 269.0848, found
The reaction with tosylate 16b (1.04g, 3.89mmol), n-BuLi (1.60 M in hexane, 2.62ml, 4.19mmol) and ketone (0.545g, 2.99mmol) in THF (33 mL) followed by collected the organic layer under vacuum affording the product 1.15g.

Then the crude benzyl alcohol with sodium azide (0.200g, 3.06mmol) in DMF (5 ml) followed by silica gel column chromatography (ethyl acetate/ petroleum ether= 10/1 to 5/1) gave azide 3b (0.730 g, 89 %) as a colorless oil.

Rf value 0.38(ethyl acetate/ petroleum ether= 1/5); 1H NMR (400 MHz, CDCl3) δ 7.59 (d, 4H, J = 7.6 Hz ), 7.34 (dd, 4H, J = 7.2, 7.6 Hz), 7.28 (d, 2H, J = 7.2 Hz), 4.31 (s, 2H), 3.63 (t, 2H, J = 6.0 Hz), 3.42 (t, 2H, J = 6.4 Hz), 2.93 (br, 1H), 1.86 (tt, 2H, J = 6.0, 6.4 Hz); 13C NMR (100 MHz, CDCl3) δ 144.7, 128.2, 127.7, 125.9, 89.1, 83.1, 74.2, 66.5, 58.5, 48.2, 28.9; HRMS (ESI) calcd for C19H19N3O2Na [M+Na]⁺ 344.1375, found 344.1373.

4-(4-azidobutoxy)-1,1-diphenylbut-2-yn-1-ol (3c)

To a stirred solution of 4-(prop-2-yn-1-yloxy)butan-1-ol (1.57 g, 12.25 mmol) and TsCl (2.80 g, 14.70 mmol) in dichloromethane (10 ml) was added triethylamine 6.11 mL, (42.87 mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO₄ followed by silica gel column chromatography (ethyl acetate/ Petroleum ether= 1/15 to 1/10) gave tosylate compound 16c (2.75 g, 80%) as a colorless oil.

Colorless oil; Rf value 0.40(ethyl acetate/ Petroleum ether= 1/5); 1H NMR (400 MHz, CDCl3) δ 7.78(d, 2H , J = 8.4 Hz), 7.34 (d, 2H, J = 8.0 Hz), 4.08-4.03 (m, 4H), 3.47 (t, 2H, J = 6.0 Hz), 2.45 (s, 3H), 2.40 (s, 1H), 1.78-1.71 (m, 2H), 1.65-1.58 (m, 2H); 13C NMR (100 MHz, CDCl3) δ 144.7, 133.1, 129.8, 127.8, 79.7, 74.3, 70.3, 68.9, 58.0, 25.7, 25.4, 21.6; HRMS (ESI) calcd for C14H19O4S [M+H]⁺ 283.1004, found 283.1008.

The reaction with tosylate 16c (1.01g, 3.57mmol), n-BuLi (1.60 M in hexane, 2.40ml, 3.84mmol) and ketone (0.500g, 2.74mmol) in THF (27 mL) followed by collected the organic layer under vacuum affording the product 0.945g.

Then the crude benzyl alcohol with sodium azide (0.159g, 2.44mmol) in DMF (5 ml) followed by silica gel column chromatography (ethyl acetate/ petroleum ether= 20/1
to 8/1) gave azide 3c (0.532 g, 78%) as a colorless oil.

Rf value 0.39(ethyl acetate/ petroleum ether= 1/5); 1H NMR (400 MHz, CDCl3) δ 7.59 (d, 4H, J = 7.6 Hz ), 7.34 (dd, 4H, J = 7.2, 7.6 Hz), 7.28 (d, 2H, J = 7.2 Hz), 4.30 (s, 2H), 3.57 (t, 2H, J = 6.0 Hz), 3.27 (t, 2H, J = 6.4 Hz), 2.87 (br, 1H), 1.67 (tt, 4H, J = 6.4, 6.0 Hz); 13C NMR (100 MHz, CDCl3) δ 144.7, 128.2, 127.6, 125.9, 88.9, 83.3, 74.2, 69.2, 58.3, 51.0, 26.5, 25.6; HRMS (ESI) calcd for C20H23N3O2Na [M+Na]+ 358.1531, found 358.1527.

4-(3-azidopropoxy)-1,1-diphenylbut-2-yn-1-ol (5)

To a stirred solution of 3-(prop-2-yn-1-ylthio)propan-1-ol (0.680g, 5.22mmol) and TsCl (1.19 g, 6.27 mmol) in dichloromethane (10 ml) was added triethylamine (1.44 mL, 18.28 mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO4 followed by silica gel column chromatography (ethyl acetate/ Petroleum ether= 1/25 to 1/10) gave tosylate compound 17 (1.17 g, 79%) as a colorless oil.

Colorless oil; Rf value 0.42(ethyl acetate/ Petroleum ether= 1/5); 1H NMR (400 MHz, CDCl3) δ 7.79(d, 2H, J = 8.4 Hz), 7.35 (d, 2H, J = 8.4 Hz), 4.15 (t, 2H, J = 6.4 Hz), 3.18 (s, 2H), 2.73 (t, 2H, J = 6.0 Hz), 2.45 (s, 3H), 2.22 (s, 1H), 1.96 (tt, 2H, J = 6.0, 6.0 Hz); 13C NMR (100 MHz, CDCl3) δ 144.8, 132.8, 129.8, 127.8, 79.5, 71.2, 68.6, 28.1, 27.3, 21.6, 19.0; HRMS (ESI) calcd for C13H17O3S2 [M+H]+ 285.0619, found 285.0619.

The reaction with tosylate 17 (0.594g, 2.09mmol), n-BuLi (1.60 M in hexane, 1.41mL, 2.25mmol) and ketone (0.293g, 1.61mmol) in THF (16 mL) followed by collected the organic layer under vacuum affording the product 0.69g.

Then the crude benzyl alcohol with sodium azide (0.155g, 3.06mmol) in DMF (5 ml) followed by silica gel column chromatography (ethyl acetate/ petroleum ether= 10/1 to 5/1) gave azide 5 (0.320 g, 64%) as a colorless oil.

Rf value 0.40(ethyl acetate/petroleum ether = 1/5); 1H NMR (400 MHz, CDCl3) δ 7.59 (d, 4H, J = 7.6 Hz ), 7.33 (dd, 4H, J = 7.2, 7.6 Hz), 7.28 (d, 2H, J = 7.2 Hz), 3.42 (s, 2H), 3.35 (t, 2H, J = 6.4 Hz), 2.74 (t, 2H, J = 6.8 Hz), 1.86 (tt, 2H, J = 6.8, 6.4 Hz); 13C NMR (100 MHz, CDCl3) δ 144.9, 128.2, 127.7, 125.9, 86.0, 83.3, 74.4, 49.9, 28.7, 28.2, 19.7; HRMS (ESI) calcd for C19H20N3OS [M+H]+ 338.1327, found 338.1325.
pent-4-yn-1-yl 4-methylbenzenesulfonate

To a stirred solution of 4-pentyn-1-ol 1 (100.0 mg, 1.19 mmol) and TsCl (249.3 mg, 1.31 mmol) in dichloromethane (12 ml) was added dropwise triethylamine (0.2 mL, 1.43 mmol) at 0 °C, then reaction mixture was allowed to warm up to ambient temperature. After 2 h, the mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO₄ followed by silica gel column chromatography (ethyl acetate / hexane = 1/10) gave tosylate (220 mg, 77.7%) as a colorless oil.

Colorless oil; Rf value 0.53 (ethyl acetate / hexane = 1/3); IR (NaCl, neat) νₘₐₓ = 3291, 2962, 1598, 1360, 1176 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.79 (d, 2H, J = 8.5 Hz), 7.35 (d, 2H, J = 8.5 Hz), 4.14 (t, 2H, J = 6.0 Hz), 2.45 (s, 3H), 2.25 (td, 2H, J = 6.5, 2.5 Hz), 1.88 (t, 1H, J = 2.5 Hz), 1.86 (tt, 2H, J = 6.5, 6.0 Hz); ¹³C NMR (126 MHz, CDCl₃) δ 144.8, 132.9, 129.8, 127.9, 82.1, 69.4, 68.7, 27.7, 21.6, 14.7; HRMS (ESI) calcd for C₁₁H₁₄O₃SNa [M+Na]⁺ 261.0561, found 261.0561.

1,11-diazido-6-phenylundeca-4,7-diyn-6-ol(7a)

The reaction with pent-4-yn-1-yl 4-methylbenzenesulfonate (1.19 g, 4.98 mmol), n-BuLi (1.55 M in hexane, 3.49 mL, 5.23 mmol) and chloride (0.35 g, 2.49 mmol) in THF (25 mL) followed by collected the organic layer under vacuum affording the crude product 2.89 g. The crude product can be used to the next step without further purification.

Then the crude benzyl alcohol with sodium azide (388.5 mg, 5.98 mmol) in DMF (25 ml) followed by silica gel column chromatography (ethyl acetate / hexane = 1/20 to 1/10 to 1/2) gave azide 7a (0.724 g, 90%) as a colorless oil.

Colorless oil; Rf value 0.51 (ethyl acetate/hexane = 1/2); IR (NaCl, neat) νₘₐₓ 3398, 2935, 2909, 1449, 1255 cm⁻¹; ¹H NMR(500 MHz, CDCl₃) δ 7.76(m, 2H), 7.35–7.41(m, 3H), 3.41(t, 4H, J = 7.0 Hz), 2.86(m, 1H, OH), 2.42(t, 4H, J = 7.0 Hz), 1.82(tt, 4H, J = 7.0, 7.0 Hz); ¹³C NMR(126 MHz, CDCl₃) δ 142.4, 128.5, 128.4, 128.4, 125.6, 83.9, 82.0, 65.0, 50.1, 27.5, 16.1; HRMS (ESI) calcd for C₁₇H₁₄N₆O₃Na [M+Na]⁺ 345.1440, found 345.1436.

1,11-diazido-6-pentylundeca-4,7-diyn-6-ol(7b)

The reaction with pent-4-yn-1-yl 4-methylbenzenesulfonate (0.915 g, 3.84 mmol), n-BuLi (1.55 M in hexane, 2.8 mL, 4.22 mmol) and ester (0.25 g, 1.92 mmol) in THF
(20 mL) followed by collected the organic layer under vacuum affording the crude product 1.10 g. The crude product can be used to the next step without further purification.

Then the crude benzyl alcohol with sodium azide (299.6 mg, 4.61 mmol) in DMF (38 ml) followed by silica gel column chromatography (ethyl acetate / hexane = 1/15 to 1/5 to 1/1) gave azide 7b (0.521 g, 86%) as a colorless oil.

Colorless oil; Rf value 0.45(ethyl acetate/hexane = 1/2); IR (NaCl, neat) νmax 3420, 2930, 2098, 1254 cm⁻¹; ¹H NMR(500 MHz, CDCl₃) δ 3.40(t, 4H, J = 7.0 Hz), 2.45(s, 1H, OH), 2.35(t, 4H, J = 7.0 Hz), 1.84–1.76(m, 6H), 1.36–1.31(m, 4H), 0.90(t, 3H, J = 7.0 Hz); ¹³C NMR(126 MHz, CDCl₃) δ 82.2, 81.9, 63.7, 50.1, 44.1, 31.4, 27.5, 24.3, 22.5, 16.0, 14.0; HRMS (ESI) calcd for C₁₆H₂₄N₆ONa [M+Na]⁺ 339.1909, found 339.1901.

5,5-bis(azidomethyl)-1,1,9,9-tetraphenylnona-2,7-diyne-1,9-diol (13)

To a stirred solution of azide compound 12¹ (0.044 g, 0.218 mmol) in dry THF (5.5 mL) under an atmosphere of nitrogen was added dropwise n-BuLi (1.60 M in hexane, 0.326 mL, 0.522 mmol) at -78 °C and the mixture was stirred for 30 min. Ketone (0.099 g, 0.544 mmol) was then added at same temperature. After 4h, the reaction was quenched with water. The mixture was diluted with ethyl acetate and was washed with water and brine. Drying collected organic layer over MgSO₄ followed by silica gel column chromatography gave 13 (112.9 mg, 92%) as colorless oil. [silica gel purification (ethyl acetate / hexane = 1 / 40 to 1/20 to 1/10)].

Colorless oil; Rf value 0.45(ethyl acetate/hexane = 1/5); ¹H NMR(400 MHz, CDCl₃) δ 7.57(d, 8H, J = 7.2 Hz), 7.32(dd, 8H, J = 6.8, 7.2 Hz), 7.28–7.25(m, 4H), 3.37 (s, 4H), 2.82(s, 2H), 2.47(s, 4H); ¹³C NMR(100 MHz, CDCl₃) δ 144.9, 128.3, 127.8, 125.8, 86.9, 82.5, 74.5, 54.4, 42.5, 23.7; HRMS (EI) calcd for C₃₅H₃₀N₆O₂ [M⁺] 566.2430, found 566.2434.

**General Experimental Procedure of triazolations**

To the mixture of propargyl alcohol (1.0 equiv) in dichloromethane (0.1 M to alcohols) under nitrogen atmosphere, acid (1.2 equiv) was added at ambient temperature. After 30 minutes, the reaction was quenched with saturated sodium bicarbonate aqueous solution, and was washed with brine. Drying the organic layer over magnesium sulfate followed by concentration in vacuo and silica gel column chromatography afforded triazole.
Diphenyl(4,5,6,7-tetrahydro-[1,2,3]triazolo[1,5-a]pyridin-3-yl)methanol (2a).

To the mixture of azido-propargyl alcohol 1a (47.0 mg, 0.154 mmol) in dichloromethane (2 mL) under nitrogen atmosphere, TFA (38.5 µL, 0.173 mmol, 1.2 equiv) was added at ambient temperature. After 30 minutes, the reaction was quenched with saturated sodium bicarbonate aqueous solution, and was washed with brine. Drying the organic layer over magnesium sulfate followed by concentration in vacuo and silica gel column chromatography afforded triazole (ethyl acetate/petroleum ether = 1/4 to 1/1) afforded 2a (44.1 mg, 94%).

Colorless oil; Rf value 0.22 (ethyl acetate/petroleum ether = 1/2); 1H NMR(500 MHz, CDCl3) δ 7.32–7.28(m, 10H), 4.34(t, 2H, J = 6.0 Hz), 4.28(br, 1H, OH), 2.00(t, 2H, J = 7.0 Hz), 1.93(m, 2H), 1.67(m, 2H); 13C NMR(126 MHz, CDCl3) δ 147.7, 145.2, 131.0, 127.9, 127.7, 127.5, 77.4, 46.6, 22.2, 20.6, 19.9; HRMS (ESI) calcd for C19H19N3ONa [M+Na]+ 328.1426, found 328.1426.

(5,6-dihydro-4H-pyrrolo[1,2-c][1,2,3]triazol-3-yl)diphenylmethanol (2b).

The reaction with propargyl alcohol (57.2 mg, 0.196 mmol) and TFA (0.015 mL, 0.236 mmol) in dichloromethane (2 ml) followed by silica gel column purification (ethyl acetate/petroleum ether = 1/5) afforded triazole 3c (56.1 mg, 98%).

White crystal; Rf value 0.10 (EtOAc/petroleum ether = 1/2); 1H NMR (500 MHz, CDCl3) δ 7.34–7.25 (m, 10H), 4.24 (t, 2H, J = 7.5 Hz), 4.19 (br-s, 1H, OH), 2.56 (tt, 2H, J = 7.5, 7.5 Hz), 2.07 (t, 2H, J = 7.5 Hz); 13C NMR (126 MHz, CDCl3) δ 145.5, 145.1, 140.2, 127.8, 127.34, 127.29, 76.6, 46.2, 27.9, 20.8; HRMS (ESI) calcd for C18H17N3ONa [M+Na]+ 314.1269, found 314.1267.

diphenyl(5,6,7,8-tetrahydro-4H-[1,2,3]triazolo[1,5-a]azepin-3-yl)methanol (2c)

The reaction with propargyl alcohol (67.7 mg, 0.212 mmol) and TFA (0.016 mL, 0.254 mmol) in dichloromethane (2 ml) followed by silica gel column purification (ethyl acetate/petroleum ether = 1/20) afforded triazole 2c (58.4 mg, 86%).

White solid; Rf value 0.37 (ethyl acetate/petroleum ether= 1/10); 1H NMR (400 MHz, CDCl3) δ 7.41–7.29 (m, 8H), 7.21–7.19 (m, 2H), 6.58 (s, 1H), 3.20 (t, 2H, J = 6.8 Hz), 2.24 (t, 2H, J = 6.8 Hz), 1.53–1.45 (m, 4H), 1.23–1.18 (m, 2H); 13C NMR (100 MHz, CDCl3) δ 141.0, 139.0, 129.5, 128.4, 128.3, 126.6, 77.2, 51.2, 42.8, 28.6, 26.2, 23.7;
HRMS (ESI) calcd for C_{20}H_{21}N_{3}ONa [M+Na]^+ 342.1582, found 342.1582.

(4,5,6,7,8,9-hexahydro-[1,2,3]triazolo[1,5-a]azocin-3-yl)diphenylmethanol (2d)

The reaction with propargyl alcohol (55.1mg, 0.165mmol) and TFA (0.013mL, 0.198 mmol) in dichloromethane (2 ml) followed by silica gel column purification (ethyl acetate/ petroleum ether = 1/20) afforded triazole 3d (46.8mg, 84%).

White solid; Rf value 0.4 (ethyl acetate/ petroleum ether= 1/10); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.41-7.29 (m, 8H), 7.21-7.19 (m, 2H), 6.58 (s, 1H), 3.22 (t, 2H, \(J = 6.8\) Hz), 2.23 (t, 2H, \(J = 6.8\) Hz), 1.57-1.46(m, 4H), 1.30-1.23(m, 2H), 1.21-1.13 (m, 2H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 141.0, 139.0, 129.5, 128.4, 128.3, 126.6, 77.2, 51.3, 42.9, 28.59, 28.57, 26.4, 24.0; HRMS (ESI) calcd for C_{21}H_{22}N_{3}ONa [M+Na]^+ 356.1739, found 356.1747.

(5,6,7,8,9,10,11,12-octahydro-4H-[1,2,3]triazolo[1,5-a][1]azacycloundecin-3-yl)diphenylmethanol (2e)

The reaction with propargyl alcohol (48.7mg, 0.130mmol) and TFA (0.010mL, 0.156 mmol) in dichloromethane (2 ml) followed by silica gel column purification (ethyl acetate/ petroleum ether = 1/10) afforded triazole 2e (35.6mg, 73%).

White solid; Rf value 0.45 (ethyl acetate/ petroleum ether= 1/10); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.40-7.28 (m, 8H), 7.20-7.19 (m, 2H), 6.58 (s, 1H), 3.25 (t, 2H, \(J = 6.8\) Hz), 2.23 (t, 2H, \(J = 6.8\) Hz), 1.61-1.54(m, 4H), 1.52-1.45(m, 2H), 1.35-1.31 (m, 10H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)) \(\delta\) 141.0, 139.0, 129.5, 128.4, 128.2, 126.6, 77.2, 51.4, 43.2, 29.22, 29.18, 29.1, 29.0, 28.8, 26.6, 24.3; HRMS (ESI) calcd for C_{24}H_{30}N_{3}O [M+H]^+ 376.2389, found 376.2388.

(5-(azidomethyl)-5,6-dihydro-4H-pyrrolo[1,2-c][1,2,3]triazol-3-yl)diphenylmethanol (2f)

The reaction with propargyl alcohol (56.7mg, 0.164mmol) and TFA (0.015mL, 0.196 mmol) in dichloromethane (2 ml) followed by silica gel column purification (ethyl acetate/ petroleum ether = 1/10 to 1/5 to 1/1) afforded triazole 2f (56.7mg, 85%).

White solid; Rf value 0.38 (ethyl acetate/ petroleum ether= 1/1); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta\) 7.32 (s, 10H), 4.44 (dd, 1H, \(J = 8.4, 12.0\) Hz), 4.12 (dd, 1H, \(J = 8.4, 12.0\) Hz), 3.49-3.38(m, 2H), 3.24-3.17(m, 1H), 2.20 (dd, 1H, \(J = 8.4, 12.0\) Hz), 1.92 (dd,
1H, J = 8.4, 12.0 Hz); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 145.6, 145.2, 138.9, 128.0, 127.6, 127.3, 76.6, 53.5, 49.5, 42.3, 25.0; HRMS (ESI) calcd for C$_{19}$H$_{19}$N$_6$O [M+H]$^+$ 347.1620, found 347.1627.

(6,7-dihydro-4H-[1,2,3]triazolo[5,1-c][1,4]oxazin-3-yl)diphenylmethanol (4a)

The reaction with propargyl alcohol (60.0 mg, 0.195 mmol) and BF$_3$·OEt$_2$ (0.029 mL, 0.234 mmol) in dichloromethane (2 ml) followed by silica gel column purification (ethyl acetate/ petroleum ether = 1/15 to 1/2 to 1/1) afforded triazole 4a (59.2 mg, 99%).

White solid; Rf value 0.25 (ethyl acetate/ petroleum ether= 1/2); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.31 (s, 10H), 4.35 (t, 2H, $J$ = 4.2 Hz), 4.12 (s, 2H), 3.99 (s, 1H), 3.93 (t, 2H, $J$ = 4.2 Hz); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 146.9, 145.1, 134.5, 128.1, 127.8, 127.4, 77.2, 63.0, 62.5, 45.7; HRMS (ESI) calcd for C$_{18}$H$_{18}$N$_3$O [M+H]$^+$ 308.1399, found 308.1402.

diphenyl(6,7,8-tetrahydro-[1,2,3]triazolo[5,1-c][1,4]oxazepin-3-yl)methanol (4b)

The reaction with propargyl alcohol (100.0 mg, 0.311 mmol) and BF$_3$·OEt$_2$ (0.046 mL, 0.373 mmol) in dichloromethane (4 ml) followed by silica gel column purification (ethyl acetate/ petroleum ether = 1/5 to 1/2 to 1/1) afforded triazole 4b (92.2 mg, 92%).

White solid; Rf value 0.18 (ethyl acetate/ petroleum ether= 1/2); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.34-7.29 (m, 10H), 4.65 (t, 2H, $J$ = 4.2 Hz), 4.08 (s, 2H), 4.03 (s, 1H), 3.95 (t, 2H, $J$ = 4.2 Hz), 2.03 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 150.1, 145.0, 134.2, 128.1, 127.8, 127.6, 77.6, 73.6, 62.1, 50.3, 29.0; HRMS (ESI) calcd for C$_{18}$H$_{20}$N$_3$O [M+H]$^+$ 322.1556, found 322.1562.

diphenyl(6,7,8,9-tetrahydro-4H-[1,2,3]triazolo[5,1-c][1,4]oxazocin-3-yl)methanol (4c)

The reaction with propargyl alcohol (45.0 mg, 0.134 mmol) and BF$_3$·OEt$_2$ (0.020 mL, 0.349 mmol) in dichloromethane (4 ml) followed by silica gel column purification (ethyl acetate/ petroleum ether = 1/5 to 1/2 to 1/1) afforded triazole 4c (38.4 mg,
85%).
White solid; Rf value 0.25 (ethyl acetate/ petroleum ether= 1/2); $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.34–7.28 (m, 10H), 4.81 (t, 2H, $J$ = 4.2 Hz), 4.10 (s, 2H), 3.65 (t, 2H, $J$ = 4.2 Hz), 1.98 (tt, 2H, $J$ = 4.2, 4.2 Hz), 1.52 (tt, 2H, $J$ = 4.2, 4.2 Hz); $^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 148.0, 144.9, 134.8, 128.2, 127.9, 127.7, 71.7, 63.4, 49.7, 29.7, 27.5, 24.5; HRMS (ESI) calcd for C$_{20}$H$_{22}$N$_3$O$_2$ [M+H]$^+$ 336.1712, found 336.1712.

diphenyl(4,6,7,8-tetrahydro-[1,2,3]triazolo[5,1-c][1,4]thiazepin-3-yl) methanol (6)

The reaction with propargyl alcohol (98.0 mg, 0.290 mmol) and BF$_3$·OEt$_2$ (0.043 mL, 0.349 mmol) in dichloromethane (4 ml) followed by silica gel column purification (ethyl acetate/ petroleum ether = 1/5 to 1/2 to 1/1) afforded triazole 6 (74.6 mg, 76%).
White crystal; Rf value 0.25 (ethyl acetate/ petroleum ether = 1/1);
$^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.35–7.28 (m, 10H), 4.57 (t, 2H, $J$ = 4.8 Hz), 3.12 (s, 2H), 2.92–2.89 (m, 2H), 2.17–2.12 (m, 2H).
$^{13}$C NMR (100 MHz, CDCl$_3$) $\delta$ 148.5, 144.8, 136.0, 128.1, 127.8, 127.7, 77.5, 50.5, 34.3, 28.8, 23.9; HRMS (ESI) calcd for C$_{19}$H$_{20}$N$_3$OS [M+H]$^+$ 338.1327, found 338.1320.

bis(5,6-dihydro-4H-pyrrolo[1,2-c][1,2,3]triazol-3-yl)(phenyl)methanol (8a)

The reaction with propargyl alcohol (117.6 mg, 0.372 mmol) and TsOH·H$_2$O (83.3 mg, 0.438 mmol) in dichloromethane (4 ml) followed by silica gel column purification (ethyl acetate/hexane = 1/5 to 1/2 to 1/1) afforded triazole 8a (100.8 mg, 86%).
White crystal; Rf value 0.14 (dichloromethane/methanol = 10/1); $^1$H NMR(500 MHz, CDCl$_3$) $\delta$ 7.57–7.55 (m, 2H), 7.31–7.28 (m, 2H), 7.25–7.22 (m, 1H), 5.72(s, 1H, OH), 4.30–4.19 (m, 4H), 2.64–2.43 (m, 8H); $^{13}$C NMR(126 MHz, CDCl$_3$) $\delta$ 144.8, 143.9, 140.2, 127.9, 127.4, 126.3, 71.9, 46.3, 27.9, 21.3; HRMS (ESI) calcd for C$_{17}$H$_{18}$N$_6$ONa [M+Na]$^+$ 345.1440, found 345.1430.

1,1-bis(5,6-dihydro-4H-pyrrolo[1,2-c][1,2,3]triazol-3-yl)hexan-1-ol (8b)
The reaction with propargyl alcohol 8b (127.1 mg, 0.402 mmol) and TMSOTf (0.087 mL, 0.482 mmol) in dichloromethane (4 ml) followed by silica gel column purification (ethyl acetate/hexane = 1/5 to 1/2 to 1/1 to ethyl acetate then methanol/dichloromethane = 1/30 to 1/20 to 1/10) afforded triazole 8b (92.1 mg, 72%). White crystal; R_f value 0.1 (methanol/dichloromethane = 1/20); ^1H NMR(500 MHz, CDCl_3) δ 4.31 (s, 1H, OH), 4.24 (t, 4H, J = 7.5 Hz), 2.98–2.87 (m, 4H), 2.71 (tt, 4H, J = 7.5, 7.5 Hz), 2.21–2.17 (m, 2H), 1.30–1.23 (m, 6H), 0.81–0.79 (m, 3H); ^13C NMR(126 MHz, CDCl_3) δ 144.7, 138.9, 71.3, 46.3, 41.4, 31.8, 28.1, 22.9, 22.5, 21.6, 14.0; HRMS (ESI) calcd for C_{16}H_{24}N_6ONa [M+Na]^+ 339.1909, found 339.1903.

(4,4',6,6'-tetrahydro-5,5'-spirobi[pyrrolo[1,2-c][1,2,3]triazole]-3,3'-diyl)bis(diphenylmethanol) (14)

To the mixture of propargyl alcohol 13 (26.6 mg, 0.047 mmol) in dichloromethane (1 ml), TsOH-H_2O (22.6 mg, 0.117 mmol) was added at ambient temperature. After 30 minutes, the reaction was quenched with saturated sodium bicarbonate aqueous solution, and was washed with brine, followed by silica gel column purification (MeOH/CH_2Cl_2 = 1/80 to 1/60 to 1/40 to 1/30) afforded triazole 14 (26.0 mg, 98%). White solid; R_f value 0.36 (MeOH/CH_2Cl_2 = 1/20); ^1H NMR(400 MHz, CDCl_3) δ 7.32–7.27 (m, 20H), 4.34(d, 2H, J = 12.0 Hz), 4.20 (d, 2H, J = 12.0 Hz), 2.92(d, 2H, J = 16.4 Hz), 2.07(d, 2H, J = 16.4 Hz); ^13C NMR(100 MHz, DMSO) δ 146.9, 146.3, 138.3, 127.6, 127.0, 126.7, 75.7, 60.1, 55.8, 34.7; HRMS (ESI) calcd for C_{35}H_{30}N_6O_2Na [M+Na]^+ 589.2328, found 589.2326.

References