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HYPERVALENT IODINE MEDIATED ONE-POT C-H FUNCTIONALIZATION AT 2α- OR 3α-POSITION OF INDOLE DERIVATIVES

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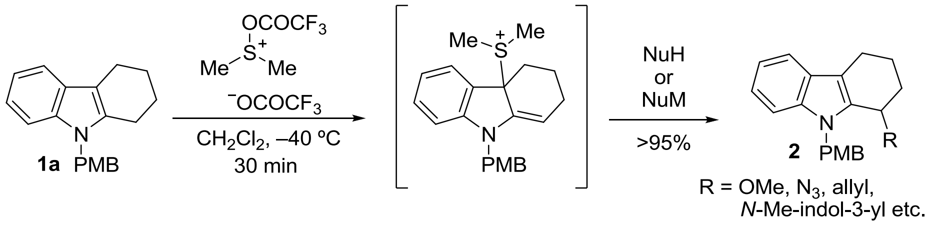
Abstract – The one-pot 2α- and 3α-functionalization of 2,3-disubstituted indoles using a hypervalent iodine reagent has been developed. The substitution at the 2α-position of indoles took place using phenyliodinebis(trifluoroacetate) with oxygen and carbon nucleophiles in moderate yields. The combination of iodosobenzene and trimethylsilyl azide afforded 3α-azide derivatives preferentially. The latter reaction was applied to other 2,3-disubstituted indoles.

INTRODUCTION

Hypervalent iodine reagents[1] having a strong leaving-group ability and electrophilicity allow a wide range of reactions, such as oxidations and C-C coupling reactions under mild conditions with a tolerance for a wide range of other functional groups. The reaction between arenes and hypervalent iodine is attractive for one of the interesting research area.[2] Especially the application of the electron-rich arenes such as indoles give rise to the substitution via cation radical intermediate,[3] indolyliodonium fragmentation,[4] and so on.[5] Recently, Ishibashi's group revealed the combination of phenyliodine diacetate (PIDA) and tetrabutylammonium iodide (TBAI) reacted with tetrahydrocarbazoles to give 2α-acetoxy derivatives.[6] Alternatively, Du Bois and co-workers developed that the reaction of tetrahydrocarbazoles using imino λ^3-iodanes with a rhodium catalyst affords 2α- and 3α-amino derivatives.[7]

Recently, we developed the concise 2α-functionalization of indole derivatives using a thionium species generated from DMSO-TFAA (Scheme 1).[8]



Scheme 1. Thionium mediated 2α-functionalization of indole derivatives

This method is useful for the introduction of various substituents to the 2α-position[9] in one-pot procedure under mild reaction conditions. However, we require a more practical method to access to 2α-functionalized indoles for the synthesis of biologically active compounds.[10] We report herein the 2α- and 3α-functionalization of indole derivatives using a hypervalent iodine reagent.

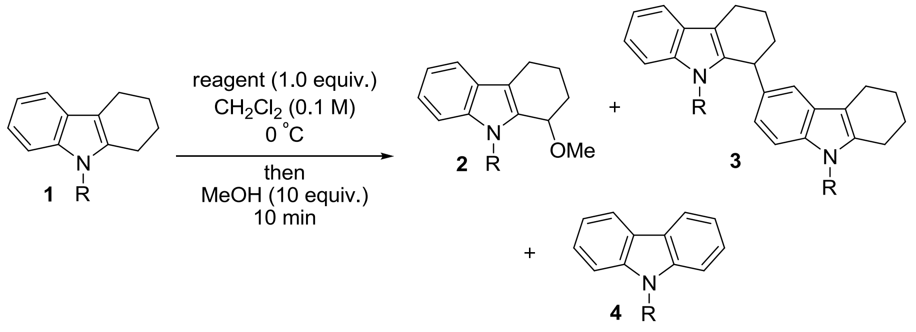
RESULTS AND DISCUSSION

Optimization of Reaction Conditions

To obtain the desired 2α-methoxy indole derivatives more conveniently, we investigated the reactivity of hypervalent iodine reagents toward *N*-*p*-methoxybenzyl (PMB)-tetrahydrocarbazole **1a** (Table 1). To a solution of **1a** in CH_2Cl_2 added one equivalent of hypervalent iodine reagent at 0 °C. After consumption of **1a**, ten equivalents of MeOH as a nucleophile was added to the reaction mixture. When Dess-Martin periodinane (DMP, entry 1) and phenyliodine diacetate (PIDA, entry 2) were used, carbazole **4** and dimer **3** was obtained respectively instead of the desired 2α-methoxy product **2a**. PhI(OH)OTs (Koser's reagent)[11] afforded a trace amount of **2a** along with dimer **3** (22%) and carbazole **4** (5%), respectively (entry 3). The use of iodopentafluorobenzene bis(trifluoroacetate) (FPIFA) as a more electrophilic λ^3–iodan produced **2a** and **3** in 8% and 29% yields, respectively (entry 4). In the case of phenyliodine bis(trifluoroacetate) (PIFA) gave **2a** in 35% yield (entry 5). The substituent effect at the indole nitrogen was examined for PIFA. *N*-Unsubstituted tetrahydrocarbazole gave a complex-mixture (entry 6) and Boc and acetyl derivatives produced a trace amount of 2α-methoxy compounds **2c** and **2d** (entries 7, 8).

Subsequently, we examined the effect of reaction temperature using PIFA (Table 2). At room temperature, the reaction afforded no desired product **2a** and gave dimer **3** in 43% yield (entry 1). When the reaction was performed at –20 °C, **2a** was given in 30% yield (entry 3). At –30 °C, the 2α-methoxy compound **2a** was obtained in 24% yield without the formation of dimer **3** (entry 4). At –40 °C, carbazole **4** was the sole product (entry 5). We concluded that the condition proceeded with PIFA at 0 °C is an optimized condition (entry 2).

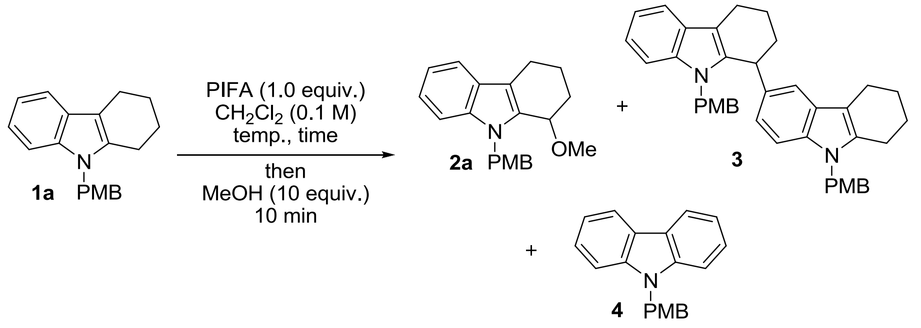
Table 1. Optimization of reaction conditions



					yield (%)			
entry	**1**	R	reagent		**2**	**3**	**4**	**1**
1	**1a**	PMB	DMP	**2a**	-	-	18	59
2	"	"	PIDA	"	-	trace	-	95
3	"	"	PhI(OH)OTs	"	trace	22	5	10
4	"	"	FPIFA	"	8	29	2	5
5	"	"	PIFA	"	35	27	4	-
6[a)]	**1b**	H	"					
7	**1c**	Boc	"	**2c**	3	-	-	28
8	**1d**	Ac	"	**2d**	9	-	-	32

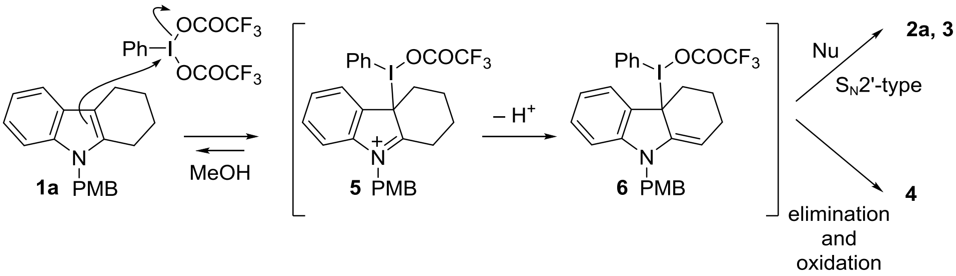
a) The reaction gave a complex-mixture.

Table 2. Effect of reaction temperature using PIFA



			yield (%)			
entry	temp. (°C)	time (min)	**2a**	**3**	**4**	**1a**
1	r.t.	15	-	43	5	13
2	0	10	35	27	4	-
3	–20	10	30	20	3	-
4	–30	50	24	-	10	22
5	–40	60	-	-	22	33

The plausible reaction mechanism is as follows (Scheme 2). First, the 3-position of **1a** attacks an iodine atom of PIFA to generate iminium intermediate **5**. Transformation of iminium **5** to enamine **6**, followed by the nucleophilic attack of MeOH afforded 2α-methoxy compound **2a**. At room temperature (Table 2, entry 1), the immediate attack of unreacted **1a** to intermediate **6** produced dimer **3** before addition of MeOH. Since **1a** was consumed at 0 °C and –20 °C (checked by TLC), the regeneration of **1a** would be caused by the attack of MeOH on the iodine atom in iminium **5**. The addition of MeOH to **6** is faster than **1a**, therefore, both yield of **2a** and ratio of **2a**/**3** were increased (entries 2 and 3). At –30 °C and –40 °C, starting material **1a** was not consumed completely and nucleophiles (**1a** and/or MeOH) react more slowly with **6**. Consequently, the elimination of iodobenzene from intermediates and the subsequent oxidation occurs to give carbazole **4** (entries 4 and 5). The structures of **2a-d** and **3** were determined by differential nOe and H-H cosy spectra (Figure 1).



Scheme 2. Plausible reaction mechanism

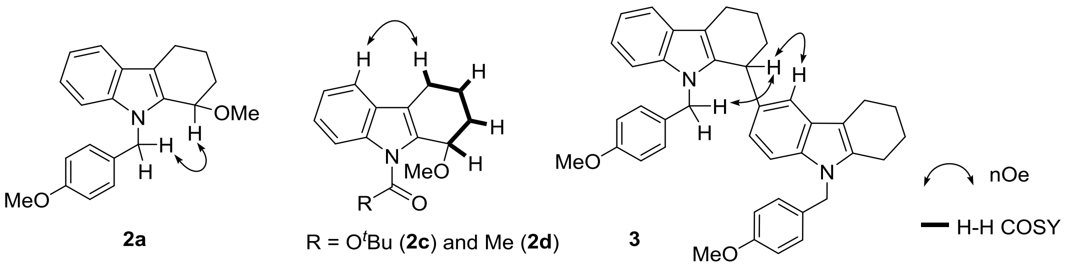
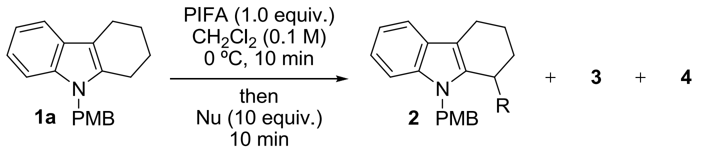


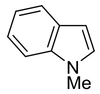
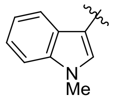
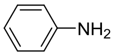
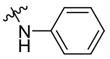
Figure 1. Structure determination of **2a-d** and **3**

Study of Nucleophiles

With the optimized conditions in hand, we investigated the scope and limitation of nucleophiles for this reaction (Table 3). As is the case in MeOH, an isopropoxy group was introduced to give **2e** in 41% yield (entry 1). The carbon nucleophiles MeMgBr and Me_2Zn gave 2α-methyl derivative **2f** in 26% and 21% yields, respectively (entries 2, 3). Vinyl and allyl groups were also introduced at the 2α-position to give products **2g** (39%) and **2h** (31%) (entries 4, 5). Additionally, the use of *N*-methylindole as an aryl nucleophile provided compound **2i** in 9% yield (entry 6). Also, the nitrogen nucleophiles, aniline and benzylamine afforded the products **2j** and **2k** in 5% and 8% yields, respectively (entries 7, 8).

Table 3. Study of nucleophiles

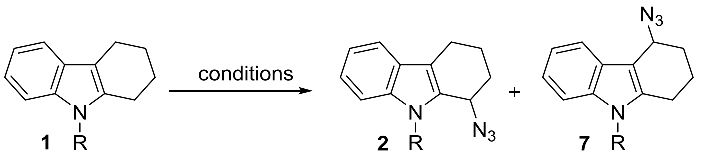


				yield (%)			
entry	Nu	R		2	3	4	1a
1	^{i}PrOH	O^{i}Pr	**2e**	41	-	10	13
2	MeMgBr	Me	**2f**	26	23	-	-
3	Me_2Zn	"	"	21	41	-	-
4	vinylMgBr	vinyl	**2g**	39	8	1	15
5	allylMgBr	allyl	**2h**	31	-	1	17
6			**2i**	9	18	-	54
7			**2j**	5	29	1	9
8	$BnNH_2$	NHBn	**2k**	8	-	-	64

3α-Azide Substituent

When $TMSN_3$ was used as a nucleophile at 0 °C for substrate **1a**, 2α-azide product **2l** was obtained in 20% yield (Table 4, entry 1, Method A). At –20 °C, 3α-azide product **7a** was produced in 45% yield along with 2α-product **2l** in 26% yield (entry 2). For *N*-Boc derivative **1c** under this reaction condition, both 2α- and 3α-substituted products **2m** and **7c** were obtained in 22% and 25% yields, respectively (entry 3).

Table 4. Azidation of **1** with the combination of hypervalent iodine and $TMSN_3$



					yields (%)				
entry	1	R	reagents	temp. (°C)	2		7		1
1	**1a**	PMB	PIFA, $TMSN_3$$^{a)}$	0	**2l**	20	**7a**	trace	18
2	"	"	"	–20	"	26	"	45	-
3	**1c**	Boc	"	"	**2m**	22	**7c**	25	11
4	**1a**	PMB	PIFA–$TMSN_3$$^{b)}$	–40	**2l**	9	**7a**	33	12
5	"	"	PhIO–$TMSN_3$$^{c)}$	"	"	9	"	43	-
6	**1c**	Boc	"	"	**2m**	21	**7c**	30	5
7	**1e**	CO_2Me	"	–40 to –25	**2n**	13	**7e**	25	4
8	**1d**	Ac	"	"	**2o**	6	**7d**	16	12

a) Method **A**: mixture of **1** and PIFA (1.0 equiv.) then addition of $TMSN_3$ (10 equiv.) in CH_2Cl_2 (0.1 M).
b) Method **B**: preformed $PhI(N_3)_2$ by PIFA (1.2 equiv.) and $TMSN_3$ (2.4 equiv.) in MeCN (0.1 M).
c) Method **B**: preformed $PhI(N_3)_2$ by PhIO (1.2 equiv.) and $TMSN_3$ (2.4 equiv.) in CH_2Cl_2 (0.1 M).

Since the treatment of **1c** with MeOH produced trace of 2α-derivative **2c** (3% yield, Table 1, entry 7), we hypothesized that the mechanism of azidation is different from that of other nucleophiles as shown in Table 3. It is known that combinations of iodosobenzene (PhIO) and $TMSN_3$ generate phenyliodine bisazide ($PhI(N_3)_2$),[12] which is an extremely labile intermediate for producing radical species.[13] Thus, we investigated the use of preformed $PhI(N_3)_2$ for the azidation[14] of **1** (Table 4, entries 4-8, Method B). To a solution of PIFA in MeCN was added $TMSN_3$ at –40 °C and the mixture was stirred for 5 min. After the addition of **1a**, 2α-azide **2l** and 3α-azide **7a** were formed in 9% and 33% yields, respectively (entry 4). The combination of PhIO and $TMSN_3$ increased the yield of **7a** to 43% (entry 5). The other substrates **1c-e** gave 3α-azide compounds **7c-e** in 16-30 % yields (entries 6-8). The position of the substituted azide group in **2** and **7** was determined by differential nOe and H-H cosy spectra (Figure 2).

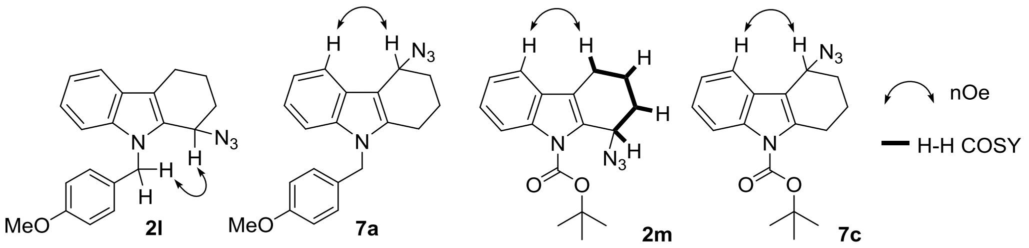
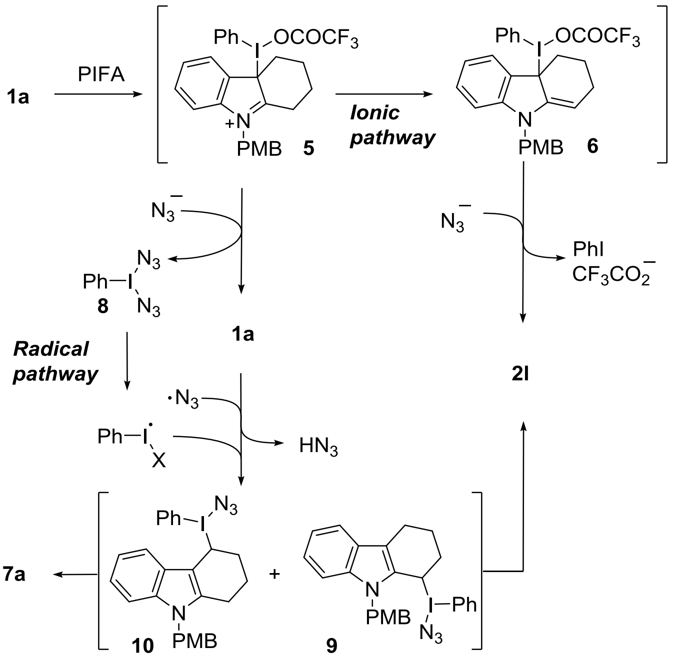


Figure 2. Structure determination of **2l**,**m** and **7a**,**c**

Based on these results, we suggest the following plausible mechanism included both ionic and radical pathways (Scheme 3). In the ionic pathway, **1a** and PIFA generate iminium **5** followed by formation of enamine **6** and then S_N2'-type reaction between the azide ion and **6** gives 2α-compound **2l**. In the radical

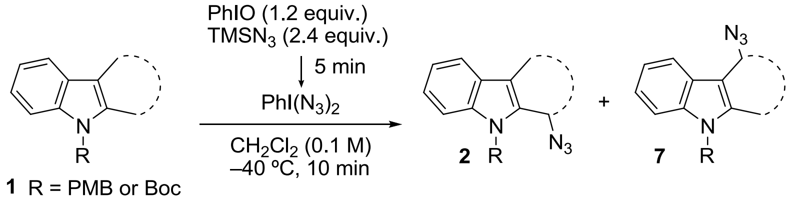


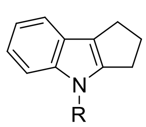
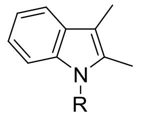
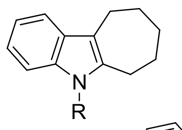
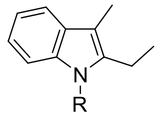
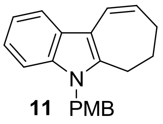
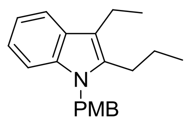
Scheme 3. Plausible reaction mechanism

pathway, the iodine atom of iminium **5** or PIFA reacts with $TMSN_3$ to produce $PhI(N_3)_2$ **8**. Then, the azide radical from **8** reacts with tetrahydrocarbazole **1a** at 2α and/or 3α position and then the generated benzylic radical coupled with the iodo radical to form intermediates **9** and **10**. Finally, reductive elimination of iodobenzene gave the corresponding products **2l** and **7a**.

Using the combination of iodosobenzene and $TMSN_3$ (Table 4, entry 5), we studied the scope and limitations of the substrates for a variety of 2,3-disubstituted indoles (Table 5). *N*-Boc cyclopenta[*b*]indole **1g** and cyclohepta[*b*]indoles **1i** produced the corresponding 2α- and 3α-azide products **2** and **7** in higher yield than *N*-PMB derivatives **1f** and **1h** (entries 1 vs 2, 3 vs 4). The reaction of cyclohepta[*b*]indole **1h** was accompanied by formation of olefin **11** in 23% yield (entry 3). In the case of 2,3-dialkyl substituted indoles, *N*-PMB derivatives gave better yields and selectivity than the *N*-Boc indoles (entries 5 vs 6, 7 vs 8). In particular, *N*-PMB-2-propyl-3-ethylindole **1n** gave only 3α-product **7n** in 75% yield (entry 9).

Table 5. Study of various 2,3-disubstituted indole derivatives



entry	1		yield (%)		entry	1		yield (%)	
			2	**7**				**2**	**7**
1		**1f**: R = PMB	**2p** 8	**7f** N.A.[a]	5		**1j**: R = PMB	**2t** 5	**7j** 50
2		**1g**: R = Boc	**2q** 13	**7g** 16	6		**1k**: R = Boc	**2u** 2	**7k** 11
3[b]		**1h**: R = PMB	**2r** 3	**7h** N.A.	7		**1l**: R = PMB	**2v** 1	**7l** 63
4		**1i**: R = Boc	**2s** 7	**7i** 18	8		**1m**: R = Boc	**2w** N.A.	**7m** 16
	 **11**				9		**1n**: R = PMB	**2x** N.A.	**7n** 75

a) N.A. means not available.
b) Compound **11** was obtained in 23 % yield.

CONCLUSION

We studied the one-pot functionalization of 2,3-substituted indoles with hypervalent iodine reagents. We developed the substitution at 2α-position of indoles using PIFA with oxygen and carbon nucleophiles, which afforded 2α-derivatives in moderate yields. In the case of the combination of PhIO and $TMSN_3$, the radical mechanism was also included to afford 3α-azide derivatives preferentially. These results provide an interesting complementary approach to our previous method using thionium species, which afforded 2α-azide derivatives.

EXPERIMENTAL

All melting points were measured on a Yanagimoto micro melting point apparatus, and are uncorrected. IR spectra were recorded on a Shimadzu IR Prestige-21 spectrophotometer. ^{1}H and ^{13}C NMR spectra were measured on a JEOL JNM-AL300 (300 MHz), a JEOL JNM-AL400 (400 MHz), a JEOL JNM-ECS400 (400 MHz), or a JEOL JNM-LA500 (500 MHz) spectrometer with tetramethylsilane as an internal standard. *J*-Values are given in Hertz. Mass spectra were recorded on a JEOL JMS 700 instrument with a direct inlet system. Thin layer chromatography (TLC) was carried out on a Merck silica gel plate 60F$_{254}$. Column chromatography was carried out on a silica gel [Fuji Silysia Co. Inc. (silica gel PSQ 60B)]. All solvents were purified by standard procedures prior to use. The following compounds were characterized by the previous reports: **1a-d, 1f-m, 2a, 2d-m, 3, 4**.[6,8,15]

Repesentative procedure for C-H functionalization of indole derivatives with hypervalent iodine reagent (Table 1-3, Table 4 entries 1-3)

Under argon atmosphere, to a solution of **1a** (92 mg, 0.31 mmol) in CH_2Cl_2 (0.1 M) was added PIFA (0.13 g, 0.31 mmol) at 0 °C. After 10 min stirring, MeOH (0.13 mL, 3.1 mmol) was added to the reaction mixture. The mixture was stirred for 10 min and quenched by aqueous sodium sulfite (3 mL) and then extracted with CH_2Cl_2 (10 mL, 3 times). The organic layer was washed by brine and dried over $MgSO_4$. The concentrated residue was purified by silica gel chromatography (AcOEt/*n*-hexane = 1/20) to give **2a**[8] (34 mg, 35%); **3**[8] (24 mg, 27%); **4**[15] (3.5 mg, 4%).

9-(*tert*-Butoxycarbonyl)-1-methoxy-1,2,3,4-tetrahydro-9*H*-carbazole (2c)

Colorless oil. IR ($CHCl_3$): 2982, 2934, 1722, 1454, 1371, 1314 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.69 (9H, s, ^{t}Bu), 1.78-2.04 (3H, m, $C\underline{H}_2CH_2CHOMe$, $CH_2C\underline{H}_2CHOMe$), 2.28 (1H, ddt, *J* = 3.0, 6.6, 13.8 Hz, $C\underline{H}_2CHOMe$), 2.53 (1H, ddd, *J* = 6.3, 11.4, 16.8 Hz, $CC\underline{H}_2CH_2$), 2.80 (1H, ddd, *J* = 2.1, 5.4, 16.2 Hz, $CC\underline{H}_2CH_2$), 3.50 (3H, s, $OC\underline{H}_3$), 5.04 (1H, t, *J* = 3.0 Hz, $C\underline{H}OMe$), 7.19 (1H, dt, *J* = 0.9, 7.2 Hz, Ar-$\underline{H}$), 7.27 (1H, dt, *J* = 1.5, 7.2 Hz, Ar-$\underline{H}$), 7.43 (1H, dd, *J* = 0.6, 8.1 Hz, Ar-$\underline{H}$), 8.02 (1H, d, *J* = 8.1 Hz, Ar-$\underline{H}$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 17.2, 21.1, 27.1, 28.3, 56.3, 70.6, 83.2, 115.7, 118.5, 119.8, 122.2, 128.9, 124.5, 134.2, 136.2, 150.3. MS (EI): *m/z* (%) 301 (M^+, 34), 214 (11), 201 (54), 170 (63), 169 (100), 168 (44), 167 (13), 57 (29). HRMS (EI): *m/z* Calcd for $C_{18}H_{23}NO_3$: 301.1678; Found: 301.1680.

9-(4-Methoxybenzyl)-1-phenylamino-1,2,3,4-tetrahydro-9*H*-carbazole (2j)

Yellow oil. IR ($CHCl_3$): 2928, 2839, 1601, 1512, 1501, 1464, 1246 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 1.77-1.91 (3H, m, $C\underline{H}_2CH_2CHN$, $CH_2C\underline{H}_2CHNHAr$), 2.17-2.27 (1H, m, $C\underline{H}_2CHNHAr$), 2.67 (1H, dt, J = 5.4, 8.7 Hz, $CC\underline{H}_2CH_2$), 2.90 (1H, dt, J = 4.2, 16.2 Hz, $CC\underline{H}_2CH_2$), 3.75 (3H, s, $OC\underline{H}_3$), 3.83 (1H, brs, $N\underline{H}Ph$), 4.65 (1H, brs, $C\underline{H}NHAr$), 5.20 (1H, d, J = 16.8 Hz, $NC\underline{H}_2Ar$), 5.31 (1H, d, J = 16.8 Hz, $NC\underline{H}_2Ar$), 6.53 (2H, d, J = 7.8 Hz, Ar-$\underline{H}$), 6.67-6.71 (1H, m, Ar-$\underline{H}$), 6.77-6.73 (2H, m, Ar-$\underline{H}$), 6.84-6.86 (2H, m, Ar-$\underline{H}$), 7.11 (1H, ddd, J = 0.9, 6.6, 7.5 Hz, Ar-$\underline{H}$), 7.17 (2H, dd, J = 7.5, 8.4 Hz, Ar-$\underline{H}$), 7.18 (1H, dt, J = 1.2, 6.6 Hz, Ar-$\underline{H}$), 7.26 (1H, dt, J = 0.9, 7.2 Hz, Ar-$\underline{H}$), 7.57 (1H, dt, J = 0.8, 7.5 Hz, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 18.4, 21.0, 28.5, 44.9, 45.8, 55.2, 109.5, 112.6, 113.0, 114.0, 117.4, 118.6, 119.0, 122.1, 126.6, 127.3, 129.3, 130.4, 134.2, 137.1, 146.3, 158.7. MS (EI) *m/z* (%): 382 (M^+, 1), 290 (23), 289 (56), 121 (100), 93 (13). HRMS (EI): *m/z* Calcd for $C_{26}H_{26}N_2O$: 382.2045; Found: 382.2040.

Representative procedure for C-H functionalization of indole derivatives with hypervalent iodine reagent (Table 4 entries 4-8, Table 5)

Under argon atmosphere, a solution of iodosobenzene (PhIO, 57 mg, 0.26 mmol) in CH_2Cl_2 (2.2 mL) was added trimethylsilyl azide ($TMSN_3$, 72 μL, 0.52 mmol) and stirred for 5 min. Subsequently, **1a** (63 mg, 0.22 mmol) was added to the reaction mixture and stirred for 60 min at –40 °C. The mixture was quenched by aqueous sodium sulfite (2 mL) and then extracted with CH_2Cl_2 (10 mL, 3 times). The organic layer was washed by brine and dried by $MgSO_4$. The concentrated residue was purified by silica gel chromatography (AcOEt/*n*-hexane = 1/20) or preparative silica gel chromatography to give **2l** (6.4 mg, 9%); **7a** (32 mg, 43%).

4-Azido-9-(4-methoxybenzyl)-1,2,3,4-tetrahydro-9*H*-carbazole (7a)

Brown oil. IR ($CHCl_3$): 2947, 2837, 2097, 1730, 1612, 1512, 1464 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 1.88-2.15 (4H, m, $CHN_3C\underline{H}_2C\underline{H}_2$, $CHN_3CH_2C\underline{H}_2$), 2.53-2.63 (1H, m, $CC\underline{H}_2$), 2.73 (1H, dt, J = 4.8, 16.2 Hz, $CC\underline{H}_2$), 3.73 (3H, s, $OC\underline{H}_3$), 4.88 (1H, t, J = 4.2 Hz, $C\underline{H}N_3$), 5.19 (2H, d, J = 1.8 Hz, $NC\underline{H}_2Ar$), 6.78-6.83 (2H, m, Ar-$\underline{H}$), 6.90-6.95 (2H, m, Ar-$\underline{H}$), 7.12-7.20 (2H, m, Ar-$\underline{H}$), 7.23-7.29 (1H, m, Ar-$\underline{H}$), 7.68-7.73 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 19.0, 21.9, 29.9, 45.8, 54.9, 55.2, 107.5, 109.4, 114.1, 118.2, 119.9, 121.6, 126.6, 127.3, 129.4, 136.6, 138.2, 158.8. HRMS (FAB): *m/z* Calcd for $C_{20}H_{20}N_4O$: 332.1637; Found: 332.1635.

4-Azido-9-(*tert*-butoxycarbonyl)-1,2,3,4-tetrahydro-9*H*-carbazole (7c)

Yellow oil. IR ($CHCl_3$): 3009, 2980, 2945, 2934, 2100, 1724, 1454, 1369, 1314 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 1.71 (9H, s, ^{t}Bu), 1.93-2.12 (4H, m, $CHN_3C\underline{H}_2CH_2$, $CHN_3CH_2C\underline{H}_2$), 2.84-3.04 (1H, m, $CC\underline{H}_2$),

3.18 (1H, dt, J = 4.8, 18.0 Hz, C$\underline{H}_2$), 4.72 (1H, t, J = 3.9 Hz, C$\underline{H}N_3$), 7.22-7.32 (2H, m, Ar-$\underline{H}$), 7.57-7.67 (1H, m, Ar-$\underline{H}$), 8.08-8.18 (1H, m, Ar-$\underline{H}$).
^{13}C NMR (75 MHz, $CDCl_3$): δ 19.5, 25.6, 28.2, 28.9, 54.2, 84.0, 114.1, 115.6, 118.0, 123.0, 124.0, 128.2, 135.8, 138.7, 150.4. MS (EI): *m/z* (%) 312 (19), 270 (16), 215 (14), 214 (100), 213 (19), 170 (66), 169 (20), 168 (30), 167 (12), 57 (41). HRMS (EI): *m/z* Calcd for $C_{17}H_{20}N_4O_2$: 312.1586; Found: 312.1585.

1-Azido-9-(methoxycarbonyl)-1,2,3,4-tetrahydro-9*H*-carbazole (2n)

White solid. mp 93-95 ºC. IR ($CHCl_3$): 2953, 2100, 1734, 1456, 1443, 1369 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.89-2.05 (3H, m, $C\underline{H}_2C\underline{H}_2CHN_3$), 2.15-2.29 (1H, m, $CH_2C\underline{H}_2CHN_3$), 2.50-2.65 (1H, m, $C\underline{H}_2$), 2.85 (1H, dt, J = 3.6, 16.8 Hz, $C\underline{H}_2$), 4.10 (3H, s, OCH_3), 5.29 (1H, t, J = 3.0 Hz, $C\underline{H}N_3$), 7.27 (1H, dt, J = 0.9, 7.5 Hz, Ar-$\underline{H}$), 7.36 (1H, dt, J = 1.2, 7.2 Hz, Ar-$\underline{H}$), 7.47 (1H, dt, J = 0.6, 7.8 Hz, Ar-$\underline{H}$), 8.15 (1H, d, J = 8.1 Hz, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 17.4, 20.8, 30.7, 53.8, 55.1, 116.0, 118.8, 121.3, 123.1, 125.5, 128.8, 131.4, 136.1, 152.0. MS (EI): *m/z* (%) 270 (M$^+$, 15), 229 (15), 228 (100), 168 (16), 167 (11). HRMS (EI): *m/z* Calcd for $C_{14}H_{14}N_4O_2$: 270.1117; Found: 270.1115.

4-Azido-9-(methoxycarbonyl)-1,2,3,4-tetrahydro-9*H*-carbazole (7e)

Yellowish white solid. mp 77-79 ºC. IR ($CHCl_3$): 2955, 2359, 2340, 2099, 1734, 1458, 1443, 1368 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.90-2.17 (4H, m, $CHN_3C\underline{H}_2C\underline{H}_2$), 2.80-3.04 (1H, m), 3.20 (1H, dt, J = 4.5, 18.3 Hz, $C\underline{H}_2$), 4.05 (3H, s, $OC\underline{H}_3$), 4.72 (1H, t, J = 4.2 Hz, $C\underline{H}N_3$), 7.30 (1H, t, J = 3.3 Hz, Ar-$\underline{H}$), 7.30 (1H, ddd, J = 1.8, 7.2, 17.1 Hz, Ar-$\underline{H}$), 7.56-7.67 (1H, m, Ar-H), 8.07-8.20 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): 19.4, 25.2, 28.9, 53.5, 54.1, 114.8, 115.6, 118.2, 123.3, 124.3, 128.3, 135.7, 138.6, 152.4. MS (EI): *m/z* (%) 270 (M$^+$, 12), 229 (15), 228 (100), 168 (16), 167 (12). HRMS (EI): *m/z* Calcd for $C_{14}H_{14}N_4O_2$: 270.1117; Found: 270.1118.

9-Acetyl-1-azido-1,2,3,4-tetrahydro-9*H*-carbazole (2o)

Brown oil. IR ($CHCl_3$): 2947, 2930, 2100, 1697, 1460, 1373, 1308 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.91-2.05 (3H, m, $C\underline{H}_2C\underline{H}_2CHN_3$), 2,12- 2.25 (1H, m, $CH_2C\underline{H}_2CHN_3$), 2.504-2.70 (1H, m, $C\underline{H}_2$), 2.84 (3H, s, $COC\underline{H}_3$), 2.81-2.91 (1H, m, $C\underline{H}_2$), 5.39 (1H, t, J = 3.0 Hz, $C\underline{H}N_3$), 7.29 (1H, dt, J = 0.9, 7.5 Hz, Ar-$\underline{H}$), 7.37 (1H, dt, J = 1.2, 7.2 Hz, Ar-$\underline{H}$), 7.51 (1H, dt, J = 0.6, 7.8 Hz, Ar-$\underline{H}$), 7.76 (1H, dt, J = 0.6, 8.1 Hz, Ar-$\underline{H}$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 17.4, 20.8, 27.4, 30.7, 55.3, 114.7, 119.5, 121.8, 123.1, 125.3, 129.5, 132.7, 135.7, 169.6. MS (EI): *m/z* (%) 254 (M$^+$, 25), 213 (11), 212 (74), 211 (17), 184 (18), 183 (17), 171 (13), 170 (100), 169 (38), 168 (56), 167 (23), 156 (12). HRMS (EI): *m/z* Calcd for $C_{14}H_{14}N_4O$: 254.1168; Found: 254.1167.

9-Acetyl-4-azido-1,2,3,4-tetrahydro-9*H*-carbazole (7d)

Colorless solid. mp 76-79 ºC. IR ($CHCl_3$): 3009, 2949, 2099, 1701, 1371, 1304 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 1.90-2.30 (4H, m, $CHN_3C\underline{H}_2C\underline{H}_2$), 2.74 (3H, s, $COC\underline{H}_3$), 2.91-3.04 (1H, m, $C\underline{H}_2$), 3.17 (1H, dt, J = 4.5, 17.7 Hz, $CC\underline{H}_2$), 4.73 (1H, t, J = 3.9 Hz, $C\underline{H}N_3$), 7.31 (1H, t, J = 3.6 Hz, Ar-$\underline{H}$), 7.31 (1H, ddd, J = 2.1, 7.2, 15.6 Hz, Ar-$\underline{H}$), 7.60-7.70 (1H, m, Ar-$\underline{H}$), 7.92-8.02 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 19.8, 26.3, 27.4, 28.7, 54.2, 115.2, 115.5, 118.6, 123.5, 124.5, 128.8, 135.7, 138.7, 170.0. MS (EI): *m/z* (%) 254 (M^+, 13), 212 (43), 211 (15), 184 (11), 171 (12), 170 (100), 169 (33), 168 (46), 167 (20), 156 (13). HRMS (EI): *m/z* Calcd for $C_{14}H_{14}N_4O$: 254.1168; Found: 254.1161.

3-Azido-4-(4-methoxybenzyl)-1,2,3,4-tetrahydrocyclopenta[*b*]indole (2p)

Brown oil. IR ($CHCl_3$): 3007, 2936, 2864, 2094, 1512, 1464, 1246 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$) δ: 2.62 (1H, ddt, J = 2.8, 7.6, 16.4 Hz, $CH_2C\underline{H}_2CHN_3$), 2.82 (1H, ddd, J = 3.6, 8.8, 14.0 Hz, $C\underline{H}_2CH_2CHN_3$), 2.95 (1H, ddt, J = 6.0, 8.0, 13.8 Hz, $CH_2C\underline{H}_2CHN_3$), 3.02-3.15 (1H, m, $C\underline{H}_2CH_2CHN_3$), 3.77 (3H, s, $OC\underline{H}_3$), 4.64 (1H, dt, J = 2.8, 9.2 Hz, $C\underline{H}N_3$), 5.19 (1H, d, J = 16.1 Hz, $NC\underline{H}_2Ar$), 5.34 (1H, d, J = 15.6 Hz, $NC\underline{H}_2Ar$), 6.77-6.89 (2H, m, Ar-$\underline{H}$), 7.03-7.08 (2H, m, Ar-$\underline{H}$), 7.10 (1H, td, J = 1.0, 8.0 Hz, Ar-$\underline{H}$), 7.17 (1H, td, J = 1.6, 8.4 Hz, Ar-$\underline{H}$), 7.25 (1H, td, J = 1.2, 8.4 Hz, Ar-$\underline{H}$), 7.52 (1H, dt, J = 0.8, 7.6 Hz, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): 23.2, 36.7, 47.6, 55.2, 60.0, 110.5, 114.1, 119.6, 119.8, 121.9, 122.2, 123.5, 127.9, 129.6, 141.2, 142.0, 159.0. MS (EI): *m/z* (%) 318 (M^+, 12), 290 (13), 276 (29), 275 (23), 121 (100). HRMS (EI): *m/z* Calcd for $C_{19}H_{18}N_4O$: 318.1481; Found: 318.1479.

3-Azido-4-(*tert*-butoxycarbonyl)-1,2,3,4-tetrahydrocyclopenta[*b*]indole (2q)

Yellowish green oil. IR ($CHCl_3$): 2980, 2936, 2099, 1730, 1368, 1319 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 1.69 (9H, s, ^{t}Bu), 2.56 (1H, ddd, J = 0.8, 6.0, 9.9 Hz, $C\underline{H}_2CH_2CHN_3$), 2.70-2.92 (2H, m, $CH_2C\underline{H}_2CHN_3$), 2.98 (1H, ddt, J = 1.5, 2.1, 12.3 Hz, $C\underline{H}_2CH_2CHN_3$), 5.10 (1H, d, J = 6.6 Hz, $C\underline{H}N_3$), 7.25 (1H, dt, J = 1.2, 7.5 Hz, Ar-$\underline{H}$), 7.33 (1H, dt, J = 1.2, 7.2 Hz, Ar-$\underline{H}$), 7.46 (1H, dd, J = 0.6, 5.7 Hz, Ar-$\underline{H}$), 8.20 (1H, d, J = 8.1 Hz, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 22.8, 28.2, 36.6, 62.0, 84.1, 116.2, 119.8, 123.0, 124.9, 125.5, 129.1, 139.8, 140.8, 149.3. MS (EI): *m/z* (%) 298 (M^+, 26), 256 (20), 242 (11), 201 (13), 200 (97), 169 (21), 157 (12), 156 (100), 155 (47), 57 (43). HRMS (EI): *m/z* Calcd for $C_{16}H_{18}N_4O_2$: 298.1430; Found: 298.1424.

1-Azido-4-(*tert*-butoxycarbonyl)-1,2,3,4-tetrahydrocyclopenta[*b*]indole (7g)

Brown oil. IR ($CHCl_3$): 3007, 2980, 2936, 2093, 1730, 1369, 1321 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 1.66 (9H, s, ^{t}Bu), 2.49 (1H, ddt, J = 3.0, 8.4, 14.4 Hz, $CHN_3C\underline{H}_2CH_2$), 2.81-2.98 (1H, m, $CHN_3C\underline{H}_2CH_2$), 3.06 (1H, ddd, J = 3.6, 8.7, 17.1 Hz, $CHN_3CH_2C\underline{H}_2$), 3.27 (1H, dddd, J = 1.8, 5,1, 7.8, 16.8 Hz, $CHN_3CH_2C\underline{H}_2$), 4.96 (1H, dt, J = 2.1, 7.8 Hz, $C\underline{H}N_3$), 7.27 (1H, ddd, J = 1.8, 7.2, 19.2 Hz, Ar-$\underline{H}$), 7.27 (1H, t, J = 2.1 Hz, Ar-$\underline{H}$), 7.52 (1H, dd, J = 2.7, 6.9 Hz, Ar-$\underline{H}$), 8.18 (1H, dd, J = 1.8, 6.6 Hz, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 27.9, 28.2, 35.6, 60.7, 83.9, 115.9, 118.7, 122.5, 123.2, 123.8, 125.1, 140.3, 146.3, 149.6. MS (EI): *m/z* (%) 298 (M^+, 14), 256 (22), 201 (13), 200 (100), 199 (16), 169 (11), 156 (56), 155 (22), 154 (12), 57 (41). HRMS (EI): *m/z* $C_{16}H_{18}N_4O_2$: 298.1430; Found: 298.1424.

6-Azido-5-(4-methoxybenzyl)-5,6,7,8,9,10-hexahydrocyclohepta[*b*]indole (2r)

Brown oil. IR ($CHCl_3$): 2930, 2100, 1512, 1464 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.50-1.75 (1H, m, $CCH_2C\underline{H}_2$), 1.83 (1H, ddt, J = 3.0, 12.0, 16.8 Hz, $C\underline{H}_2CHN_3$), 1.90-2.12 (3H, m, $CCH_2C\underline{H}_2C\underline{H}_2$), 2.20 (1H, ddt, J = 2.4, 5.1, 13.2 Hz, $C\underline{H}_2CHN_3$), 2.86 (1H, ddd, J = 2.7, 11.7, 14.7 Hz, $CC\underline{H}_2$), 3.10 (1H, ddd, J = 2.4, 6.0, 15.9 Hz, $CC\underline{H}_2$), 3.76 (3H, s, $OC\underline{H}_3$), 4.76 (1H, dd, J = 2.7, 5.4 Hz, $C\underline{H}N_3$), 5.32 (1H, d, J = 17.1 Hz, $NC\underline{H}_2Ar$), 5.41 (1H, d, J = 17.1 Hz, $NC\underline{H}_2Ar$), 6.76-6.85 (2H, m, Ar-$\underline{H}$), 6.85-6.95 (2H, m, Ar-$\underline{H}$), 7.14 (1H, ddd, J = 1.5, 6.9, 8.1 Hz, Ar-$\underline{H}$), 7.21 (1H, dt, J = 1.2, 6.6 Hz, Ar-$\underline{H}$), 7.27 (1H, d, J = 7.2 Hz, Ar-$\underline{H}$), 7.61 (1H, d, J = 6.9 Hz, Ar-$\underline{H}$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 23.7, 24.8, 27.9, 32.3, 46.0, 55.2, 57.1, 109.6, 114.2, 117.5, 119.0, 119.4, 122.6, 126.9, 127.3, 129.8, 132.9, 136.4, 158.9. MS (EI): *m/z* (%) 346 (M^+, 3), 304 (21), 303 (57), 121 (100). HRMS (EI): *m/z* Calcd for $C_{21}H_{22}N_4O$: 346.1794; Found: 346.1791.

5-(4-Methoxybenzyl)-5,6,7,8-tetrahydrocyclohepta[*b*]indole (11)

Green oil. IR ($CHCl_3$): 2932, 1612, 1512, 1468, 1248 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.02 (2H, quint, J = 5.7 Hz, $CH_2C\underline{H}_2CH_2$), 2.46 (2H, dd, J = 5.1, 10.8 Hz, $CHC\underline{H}_2CH_2$), 2.95 (2H, t, J = 5.7 Hz, $CC\underline{H}_2CH_2$), 3.74 (3H, s, $OC\underline{H}_3$), 5.24 (2H, s, $NC\underline{H}_2Ar$), 5.74 (1H, dt, J = 5.7, 11.4 Hz, $CHC\underline{H}CH_2$), 6.68 (1H, dt, J = 1.5, 11.4 Hz, $C\underline{H}CHCH_2$), 6.73-6.84 (2H, m, Ar-$\underline{H}$), 6.85-7.00 (2H, m, Ar-$\underline{H}$), 7.08-7.18 (2H, m, Ar-$\underline{H}$), 7.18-7.22 (1H, m, Ar-$\underline{H}$), 7.60-7.70 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.3, 28.3, 30.6, 45.9, 55.2, 109.0, 110.8, 114.2, 117.6, 119.6, 120.0, 121.3, 125.3, 127.2, 127.5, 129.7, 136.3, 138.6, 158.8. MS (EI): *m/z* (%) 303 (M^+, 44), 121 (100). HRMS (EI): *m/z* Calcd for $C_{21}H_{21}NO$: 303.1623; Found: 303.1622.

6-Azido-5-(*tert*-butoxycarbonyl)-5,6,7,8,9,10-hexahydrocyclohepta[*b*]indole (2s)

Dark green oil. IR ($CHCl_3$): 2932, 2104, 1722, 1454, 1371, 1360, 1315, 1308 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.71 (9H, s, ^{t}Bu), 1.45-1.81 (1H, m, $CHN_3CH_2CH_2C\underline{H}_2$), 1.81-1.98 (2H, m, $CHN_3C\underline{H}_2C\underline{H}_2$), 1.98-2.13 (2H, m, $CHN_3CH_2C\underline{H}_2C\underline{H}_2$), 2.13-2.23 (1H, m, $CHN_3C\underline{H}_2$), 2.75-2.97 (2H, m, $CC\underline{H}_2$), 5.92 (1H, dd, J = 2.1, 6.3 Hz, $C\underline{H}N_3$), 7.24 (1H, dt, J = 1.2, 7.5 Hz, Ar-$\underline{H}$), 7.31 (1H, dt, J = 1.5, 7.2 Hz, Ar-$\underline{H}$), 7.50 (1H, dt, J = 0.6, 7.5 Hz, Ar-$\underline{H}$), 8.04 (1H, dt, J = 1.2-7.5 Hz, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 23.1, 24.4, 26.6, 28.3, 31.5, 57.4, 84.5, 115.8, 118.7, 122.6, 124.8, 124.9, 129.3, 134.4, 135.5, 150.6. MS (EI): *m/z* (%) 326 (M^+, 20), 228 (34), 227 (30), 226 (16), 185 (15), 184 (100), 183 (30), 182 (32), 180 (30), 169 (15), 168 (14), 57 (42). HRMS (EI): *m/z* Calcd for $C_{18}H_{22}N_4O_2$: 326.1743; Found: 326.1746.

10-Azido-5-(*tert*-butoxycarbonyl)-5,6,7,8,9,10-hexahydrocyclohepta[*b*]indole (7i)

Dark green oil. IR ($CHCl_3$): 2981, 2932, 2102, 1726, 1456, 1371, 1354, 1312 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.69 (9H, s, ^{t}Bu), 1.60-1.80 (1H, m, $CHN_3CH_2CH_2C\underline{H_2}$), 1.82-1.98 (2H, m, $CHN_3C\underline{H_2}C\underline{H_2}$), 1.98-2.16 (2H, m, $CHN_3CH_2C\underline{H_2}C\underline{H_2}$), 2.16-2.36 (1H, m, $CHN_3C\underline{H_2}$), 3.15 (1H, ddd, *J* = 2.4, 9.9, 17.1 Hz, $C\underline{H_2}$), 3.45 (1H, ddd, *J* = 2.4, 8.1, 17.1 Hz, $C\underline{H_2}$), 5.10 (1H, dd, *J* = 1.8, 5.7 Hz, $C\underline{H}N_3$), 7.20-7.30 (2H, m, Ar-$\underline{H}$), 7.44-7.60 (1H, m, Ar-$\underline{H}$), 7.94-8.07 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 24.4, 26.5, 27.3, 28.3, 31.5, 56.5, 84.2, 115.2, 117.2, 117.5, 122.8, 123.8, 129.3, 135.2, 142.3, 150.6. MS (EI): *m/z* (%) 326 (M$^+$, 19), 284 (17), 283 (25), 229 (15), 228 (100), 227 (89), 185 (10), 184 (76), 183 (57), 182 (51), 180 (12), 169 (11), 168 (31), 167 (18), 57 (66). HRMS (EI): *m/z* Calcd for $C_{18}H_{22}N_4O_2$: 326.1743; Found: 326.1742.

2-(Azidomethyl)-1-(4-methoxybenzyl)-3-methyl-1*H*-indole (2t)

Brown oil. IR ($CHCl_3$): 3007, 2936, 2108, 1512, 1248 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.40 (3H, s, $C\underline{H_3}$), 3.75 (3H, s, $OC\underline{H_3}$), 4.40 (2H, s, $C\underline{H_2}N_3$), 5.33 (2H, s, $NC\underline{H_2}Ar$), 6.74-6.83 (2H, m, Ar-$\underline{H}$), 6.86-6.95 (2H, m, Ar-$\underline{H}$), 7.14 (1H, ddd, *J* = 1.5, 6.3, 7.5 Hz, Ar-$\underline{H}$), 7.22 (1H, dt, *J* = 1.5, 8.1 Hz, Ar-$\underline{H}$), 7.24-7.29 (1H, m, Ar-$\underline{H}$), 7.61 (1H, dt, *J* = 1.2, 7.8 Hz, Ar-$\underline{H}$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 8.9, 44.2, 46.3, 55.2, 109.6, 111.9, 114.2, 119.3, 119.4, 122.8, 127.1, 127.8, 128.9, 129.8, 137.1, 158.9. MS (EI): *m/z* (%) 306 (M$^+$, 23), 278 (28), 264, (21), 157 (15), 121 (100). HRMS (EI): *m/z* Calcd for $C_{18}H_{18}N_4O$: 306.1480; Found: 306.1478.

3-(Azidomethyl)-1-(4-methoxybenzyl)-2-methyl-1*H*-indole (7j)

Brown oil. IR ($CHCl_3$): 3007, 2936, 2106, 1512, 1248 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 2.39 (3H, s, $C\underline{H_3}$), 3.75 (3H, s, $OC\underline{H_3}$), 4.55 (2H, s, $C\underline{H_2}N_3$), 5.28 (2H, s, $NC\underline{H_2}Ar$), 6.76-6.82 (2H, m, Ar-$\underline{H}$), 6.86-6.93 (2H, m, Ar-$\underline{H}$), 7.11-7.20 (2H, m, Ar-$\underline{H}$), 7.22-7.28 (1H, m, Ar-$\underline{H}$), 7.59-7.68 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 10.4, 45.4, 46.2, 55.3, 105.8, 109.4, 114.2, 117.9, 120.0, 121.7, 127.1, 127.5, 129.4, 136.0, 136.5, 158.9. MS (EI): *m/z* (%) 306 (M$^+$, 12), 278 (16), 264 (27), 121 (100). HRMS (EI): *m/z* Calcd for $C_{18}H_{18}N_4O$: 306.1481; Found: 306.1478.

2-(Azidomethyl)-1-(*tert*-butoxycarbonyl)-3-methyl-1*H*-indole (2u)

Yellowish green oil. IR ($CHCl_3$): 2982, 2928, 2102, 1724, 1454, 1357, 1339, 1329 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.71 (9H, s, ^{t}Bu), 2.32 (3H, s, $C\underline{H_3}$), 4.78 (2H, s, $C\underline{H_2}N_3$), 7.27 (1H, dt, *J* = 1.2, 9.6 Hz, Ar-$\underline{H}$), 7.35 (1H, dt, *J* = 1.5, 7.2 Hz, Ar-$\underline{H}$), 7.52 (1H, dd, *J* = 0.9, 7.5 Hz, Ar-$\underline{H}$), 8.12 (1H, d, *J* = 9.6 Hz, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 8.8, 28.2, 45.6, 84.4, 115.9, 119.06, 119.11, 122.7, 125.3, 129.4, 129.7, 136.1, 150.2. MS (EI): *m/z* (%) 286 (M$^+$, 34), 230 (13), 188 (28), 186 (26), 159 (16), 158 (32), 157 (29), 145 (13), 144 (100), 143 (24), 130 (25), 57 (80), 41 (11). HRMS (EI): *m/z* Calcd for $C_{15}H_{18}N_4O_2$:

286.1430; Found: 286.1428.

3-(Azidomethyl)-1-(*tert*-butoxycarbonyl)-2-methyl-1*H*-indole (7k)

Yellowish green oil. IR ($CHCl_3$): 2982, 2934, 2108, 1730, 1458, 1358 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.70 (9H, s, ^{t}Bu), 2.63 (3H, s, C$\underline{H}_3$), 4.46 (2H, s, C$\underline{H}_2$N$_3$), 7.21-7.35 (2H, m, Ar-$\underline{H}$), 7.53 (1H, ddd, *J* = 3.9, 5.2, 10.1 Hz, Ar-$\underline{H}$), 8.12 (1H, ddd, *J* = 4.5, 5.4, 11.4 Hz, Ar-$\underline{H}$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 14.0, 28.2, 44.5, 84.1, 112.3, 115.5, 117.7, 122.9, 124.0, 128.8, 135.6, 136.6, 150.5. MS (EI): *m/z* (%) 286 (M$^+$, 47), 230 (39), 213 (11), 188 (76), 158 (25), 157 (23), 145 (12), 144 (100), 143 (17), 130 (14), 57 (89), 41 (12). HRMS (EI): *m/z* Calcd for $C_{15}H_{18}N_4O_2$: 286.1430; Found: 286.1427.

2-(1-Azidoethyl)-1-(4-methoxybenzyl)-3-methyl-1*H*-indole (2v)

Yellow oil. IR ($CHCl_3$) 3007, 2932, 2106, 1512, 1466, 1246 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.47 (3H, d, *J* = 7.2 Hz, CHN$_3$C$\underline{H}_3$), 2.43 (3H, s, CC$\underline{H}_3$), 3.75 (3H, s, OC$\underline{H}_3$), 5.05 (1H, q, *J* = 7.2 Hz, C$\underline{H}$N$_3$), 5.37 (1H, d, *J* = 17.4 Hz, NC$\underline{H}_2$Ar), 5.46 (1H, d, *J* = 17.4 Hz, NC$\underline{H}_2$Ar), 6.75-6.83 (2H, m, Ar-$\underline{H}$), 6.84-6.93 (2H, m, Ar-$\underline{H}$), 7.10-7.18 (3H, m, Ar-$\underline{H}$), 7.59-7.63 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (75 MHz, $CDCl_3$): δ 9.0, 20.5, 46.8, 53.8, 55.2, 109.7, 114.1, 119.0, 119.3, 122.5, 126.9, 128.2, 130.0, 133.2, 137.0, 144.7, 158.9. MS (EI): *m/z* (%) 320 (M$^+$, 24), 278 (33), 277 (29), 122 (12), 121 (100). HRMS (EI): *m/z* Calcd for $C_{19}H_{20}N_4O$: 320.1637; Found: 320.1635.

3-(Azidomethyl)-2-ethyl-1-(4-methoxybenzyl)-1*H*-indole (7l)

Brown oil. IR ($CHCl_3$): 3007, 2970, 2936, 2108, 1512, 1466, 1248 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.17 (3H, t, *J* = 7.5 Hz, CH$_2$C$\underline{H}_3$), 2.79 (2H, q, *J* = 7.5 Hz, C$\underline{H}_2$CH$_3$), 3.73 (3H, s, OC$\underline{H}_3$), 4.54 (2H, s, C$\underline{H}_2$N$_3$), 5.29 (2H, s, NC$\underline{H}_2$Ar), 6.74-6.81 (2H, m, Ar-$\underline{H}$), 6.83-6.90 (2H, m, Ar-$\underline{H}$), 7.10-7.22 (3H, m, Ar-$\underline{H}$), 7.60-7.68 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 15.4, 17.9, 45.5, 46.1, 55.2, 105.1, 109.8, 114.2, 118.1, 120.1, 121.8, 127.0, 127.7, 129.6, 136.5, 141.9, 158.9. MS (EI): *m/z* (%) 320 (M$^+$, 14), 278 (31), 121 (100). HRMS (EI): *m/z* Calcd for $C_{19}H_{20}N_4O$: 320.1637; Found: 320.1638.

3-(1-Azidomethyl)-1-(*tert*-butoxycarbonyl)-2-ethyl-1*H*-indole (7m)

Yellow oil. IR ($CHCl_3$): 2982, 2108, 1730, 1458, 1371, 1360, 1329 cm^{-1}. ^{1}H NMR (300 MHz, $CDCl_3$): δ 1.27 (3H, t, *J* = 7.2 Hz, CH$_2$C$\underline{H}_3$), 1.70 (9H, s, ^{t}Bu), 3.09 (2H, q, *J* = 7.2 Hz, C$\underline{H}_2$CH$_3$), 4.45 (2H, s, C$\underline{H}_2$N$_3$), 7.25 (1H, dt, *J* = 2.4, 7.8 Hz, Ar-$\underline{H}$), 7.29 (1H, dt, *J* = 2.4, 7.2 Hz, Ar-H), 7.50-7.58 (1H, m, Ar-$\underline{H}$), 8.12 (1H, dd, *J* = 1.8, 6.6 Hz, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 15.4, 20.1, 28.2, 44.7, 84.2, 111.9, 115.7, 118.0, 123.0, 124.1, 128.8, 135.9, 142.5, 150.2. MS (EI) *m/z* (%): 300 (M$^+$, 44), 244 (36), 216 (13), 203 (12), 202 (89), 172 (32), 171 (35), 159 (12), 158 (100), 157 (21), 156 (24), 155 (12), 144 (13), 143 (12), 57 (86), 41

(12). HRMS (EI): *m/z* Calcd for $C_{16}H_{20}N_4O_2$: 300.1586; Found: 300.1583.

3-Ethyl-1-(4-methoxybenzyl)-2-propyl-1*H*-indole (1n)

To a suspension of NaH (128 mg, 60% in mineral oil, 3.21 mmol) in dry DMF (5.0 mL) was added 3-ethyl-2-propylindole[16] (400 mg, 214 mmol) at 0 °C. After stirring at room temperature for 10 min, the reaction mixture was added tetrabutylammonium iodide (79 mg, 0.214 mmol) and *p*-methoxybenzyl chroride (260 μL, 2.57 mmol) and stirred for 30 min. The reaction was quenched by the addition of saturated aqueous NH_4Cl (10 mL) and extracted with Et_2O (30 mL, 3 times). The organic layer was dried over $MgSO_4$ and filtrate was concentrated. The residue was purified by silica gel chromatography (AcOEt/*n*-hexane = 1/5) to afford **1n** (504 mg, 77%).

Yellow oil. IR ($CHCl_3$): 3005, 2963, 2932, 2870, 1612, 1512, 1468, 1246 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ 0.93 (3H, t, *J* = 7.2 Hz, $CH_2CH_2C\underline{H}_3$), 1.23 (3H, t, *J* = 7.2 Hz, $CCH_2C\underline{H}_3$), 1.50 (2H, ddd, *J* = 7.2, 15.2, 15.2 Hz, $CH_2C\underline{H}_2CH_3$), 2.66 (2H, t, *J* = 8.0 Hz, $C\underline{H}_2CH_2CH_3$), 2.76 (2H, q, *J* = 7.2 Hz, $CC\underline{H}_2CH_3$), 3.71 (3H, s, $OC\underline{H}_3$), 5.22 (2H, s, $NC\underline{H}_2Ar$), 6.70-6.82 (2H, m, Ar-$\underline{H}$), 6.82-6.92 (2H, m, Ar-$\underline{H}$), 7.02-7.10 (2H, m, Ar-$\underline{H}$), 7.11-7.22 (1H, m, Ar-$\underline{H}$), 7.54-7.61 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 15.6, 17.5, 19.4, 25.3, 28.1, 47.5, 56.7, 110.9, 115.5 (2C), 119.8, 120.3, 122.2, 128.5, 129.3, 132.0, 137.8, 138.0, 160.2. MS (EI): *m/z* (%) 308 ([M^++1], 12), 307 (M^+, 52), 121 (100). HRMS (EI): *m/z* Calcd for $C_{21}H_{25}NO$: 307.1936; Found: 307.1936.

3-(1-Azidoethyl)-1-(4-methoxybenzyl)-2-propyl-1*H*-indole (7n)

Yellowish green oil. IR ($CHCl_3$): 3007, 2961, 2934, 2872, 2104, 1612, 1512, 1466, 1248, 1223 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ 0.95 (3H, t, *J* = 7.2 Hz, $CH_2CH_2C\underline{H}_3$), 1.42-1.62 (2H, m, $CH_2C\underline{H}_2CH_3$), 1.69 (3H, d, *J* = 6.9 Hz, $CHN_3C\underline{H}_3$), 2.71 (2H, t, *J* = 7.8 Hz, $CC\underline{H}_2$), 3.73 (3H, s, $OC\underline{H}_3$), 5.04 (1H, q, *J* = 6.9 Hz, $CC\underline{H}N_3$), 5.25 (2H, s, $NC\underline{H}_2Ar$), 6.74-6.82 (2H, m, Ar-$\underline{H}$), 6.82-6.90 (2H, m, Ar-$\underline{H}$), 7.06-7.21 (3H, m, Ar-$\underline{H}$), 7.75-7.83 (1H, m, Ar-$\underline{H}$). ^{13}C NMR (100 MHz, $CDCl_3$): δ 14.0, 21.5, 24.0, 26.6, 46.0, 55.2, 55.5, 109.8, 110.9, 114.1, 119.56, 119.64, 121.4, 125.7, 126.9, 129.6, 136.8, 138.2, 158.8. MS (EI): *m/z* (%) 348 (M^+, 1), 306 (14), 305 (44), 122 (10), 121 (100). HRMS (EI): *m/z* Calcd for $C_{21}H_{24}N_4O$: 348.1950; Found: 348.1946.

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