Gold(I)-Catalyzed Cascade Cyclization of Anilines with Diynes: Controllable Formation of Eight-Membered Ring-Fused Indoles and Propellane-Type Indolines

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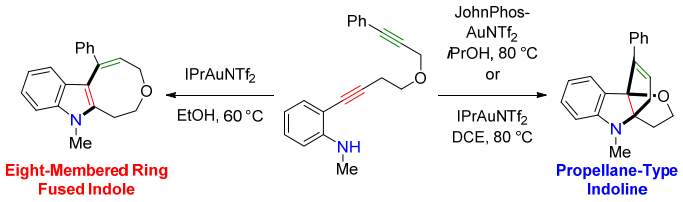


Abstract: Heterocycle-fused indoles or indolines are distributed widely in a variety of natural products, bioactive agents and pharmaceuticals. Herein, we describe the development of gold-catalyzed cascade reactions of anilines with diynes to form eight-membered ring-fused indoles and propellane-type indolines, both of which proceed through an intramolecular 5-*endo-dig* hydroamination followed by an 8-*endo-dig* cycloisomerization. Controllable formation of eight-membered ring-fused indoles and propellane-type indolines was achieved through selection of the ligands and/or solvents. Protic solvents such as alcohols or IPr ligand favored the formation of

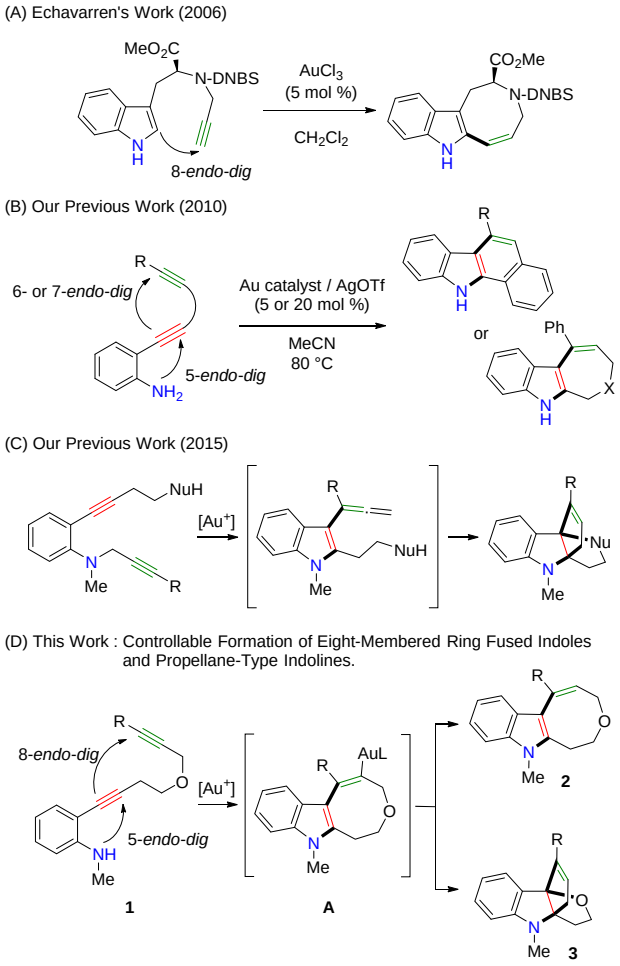
eight-membered ring-fused indoles, whereas the use of Buchwald's type ligands and/or non-polar solvents gave propellane-type indoline predominantly. This reaction provides rapid access to two types of fused nitrogen heterocycles from simple aniline derivatives.

INTRODUCTION

Heterocycle-fused indoles or indolines are core structures of various natural products, bioactive agents and pharmaceuticals.[1,2] Indoles fused with sp^3-rich medium-sized rings are important scaffolds that escape 'flatland' compound libraries for drug discovery.[3] Propellane-type indolines bearing a clear three-dimensional structure are also attractive because appropriate functional groups can be introduced to the indoline template in the desired direction. In view of these features, considerable efforts have been made to explore efficient strategies for the synthesis of those structures.[4-6]

Gold-catalyzed cascade reactions are powerful synthetic methods for the construction of medium-sized ring-fused indoles.[5] In 2006, Echavarren et al. developed a facile annulation of eight-membered ring-fused indoles by cyclization with alkyne in the presence of Au(III) species (Scheme 1A).[7] Our group has reported a direct and concise synthetic method for the generation of 2,3-fused indoles, using a gold-catalyzed cascade cyclization of diynes through an intramolecular cascade 5-*endo*-*dig* hydroamination followed by a 6- or 7-*endo*-*dig* cycloisomerization (Scheme 1B).[8] We also reported that gold-catalyzed cascade cyclization of 2-alkynyl-*N*-propargylanilines provides propellane-type indolines via rearrangement of the propargyl group (Scheme 1C).[9] Following these works, we have designed a direct synthetic method for the formation of eight-membered ring-fused indoles, such as oxocine-fused indoles **2**, through an intramolecular 5-*endo*-*dig* hydroamination followed by an 8-*endo*-*dig* cycloisomerization (Scheme 1D). During the course of this study, we found that a propellane-type indoline **3** was obtained as a side product.

Echavarren and coworkers also observed related indoline formation in limited cases, depending on the substrate structure.[7b] However, controllable formation of these two heterocycles from easily available diyne substrates based on reaction conditions has not been reported. Herein, we report ligand- and/or solvent-controlled divergent access to oxocine-fused indoles **2** and propellane-type indolines **3** via gold-catalyzed cascade cyclization (Scheme 1D).



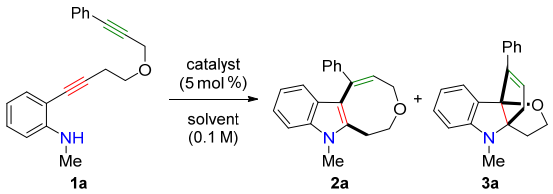
Scheme 1. Related researches and this work.

RESULTS AND DISCUSSION

We initiated our study by optimizing the reaction conditions of the cascade cyclization of the *N*-methylaniline **1a** bearing two alkyne moieties (Table 1). The reaction of **1a** with 5 mol %

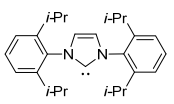
PPh_3AuNTf_2 in *i*-PrOH at 80 °C yielded no observation of the desired oxocine-fused indole **2a** (entry 1).[10] Changing the catalyst to $IPrAuNTf_2$ gave the oxocine-fused indole **2a** in 65% yield along with, unexpectedly, a propellane-type indoline **3a** in 27% yield (entry 2). Use of $IPrAuSbF_6$·MeCN caused a decrease in the yield of **2a** (42%, entry 3). The reaction in MeOH and EtOH improved the yield of **2a** (74% and 82%, entries 4 and 5). Interestingly, when using 1,2-dichloroethane or toluene instead of *i*-PrOH as a solvent, the selectivity was switched, resulting in the favorable production of the propellane-type indoline **3a** (entries 6 and 7). Further investigation revealed that the reaction with Buchwald's type ligands such as JohnPhos or BrettPhos instead of IPr also gave indoline **3a** as the major form (entries 8–10). Taken together, choices of the catalysts and/or solvents were found to be crucial for controlling the formation of the two different products: the use of IPr ligands and alcoholic solvents provided the oxocine-fused indole **2a** predominantly, whereas the use of Buchwald's type ligands and/or non-polar solvents favored the formation of propellane-type indoline **3a**.

Table 1. Optimization of the reaction conditions.

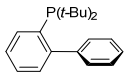


Entry	Catalyst[a]	solvent	Temp (°C)	Yield (%)[b,c]	
				2a	**3a**
1	PPh_3AuNTf_2	*i*-PrOH	80	0	0
2	$IPrAuNTf_2$	*i*-PrOH	80	65	27
3	$IPrAuSbF_6$·MeCN	*i*-PrOH	80	42	25
4	$IPrAuNTf_2$	MeOH	60	74	9
5	$IPrAuNTf_2$	EtOH	60	82 (85)	11 (7)
6	$IPrAuNTf_2$	DCE	80	4	86
7	$IPrAuNTf_2$	toluene	80	10	66

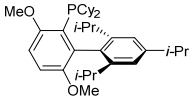
8	JohnPhosAuNTf$_2$	*i*-PrOH	80	8 (8)	88 (81)
9	JohnPhosAuSbF$_6$·MeCN	*i*-PrOH	80	6	86
10	BrettPhosAuNTf$_2$	*i*-PrOH	80	8	80



IPr



JohnPhos



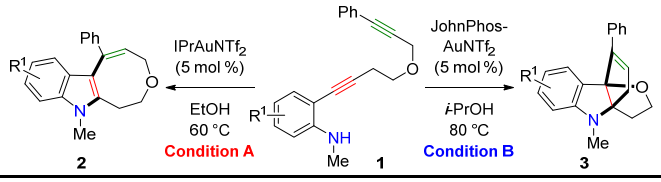
BrettPhos

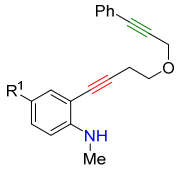
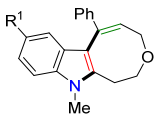
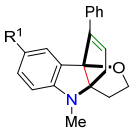
[a] The ligand structures are shown above. [b] Determined by ^{1}H NMR spectroscopy using 1,2,4,5-tetrachloro-3-nitrobenzene as an internal standard. [c] Yields in parentheses are the isolated yield on a 1.0 mmol scale.

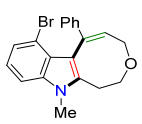
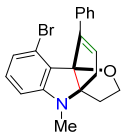
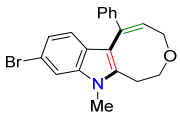
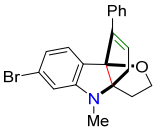
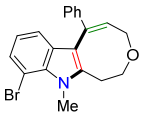
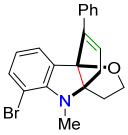
With the two optimized reaction conditions for the formation of **2a** (Table 1, entry 5 as condition A) and **3a** (entry 8 as condition B) in hand, we proceeded to evaluate the substrate scope of the reaction (Table 2). The use of anilines with halogen (F, Cl, Br) groups at the *m*-position to the alkyne resulted in the formation of the desired products **2b** (68%), **2c** (64%) and **2d** (62%) under condition A, and **3b** (67%), **3c** (79%) and **3d** (82%) under condition B (entries 1–6). Anilines **1e** and **1f** bearing an electron-donating methyl or methoxy group also gave the desired fused-indoles **2e**/**f** and indolines **3e**/**f** (entries 7-10). Unfortunately, an electron-withdrawing cyano group-containing substrate **1g** gave much lower yields of **2g** (17% under condition A) and no propellane-type indoline products using both conditions (entries 11 and 12). The indole immediate resulting from the first cyclization was observed. Thus, the poor yields of **2g** can be explained by the low nucleophilicity of the indole intermediate, assuming that a cyano group does not inhibit these reactions (*vide infra*, Table 3). The influence of the substituted position of the aniline substrates on the reaction course was evaluated using Br substituted derivatives. In the case of the aniline **1h** bearing a Br group at the *o*-position to the alkyne (entries 13 and 14), the reaction under condition A produced no oxocine-fused indole, whereas the reaction under condition B furnished propellane-type indoline **3h** in a moderate yield (44%). When using *m*- or *p*-brominated anilines **1i** and **1j**, respectively, the cascade reaction worked well to provide the corresponding oxocine-fused indoles

2i (64%) and **2j** (71%) under condition A, and propellane-type indolines **3i** (79%) and **3j** (80%) under condition B (entries 15–18). These results clearly demonstrated that steric repulsion between the *o*-Br group and phenyl group interferes with the formation of the oxocine of **2h**.

Table 2. Substrate scope (1).



Entry	Substrate	Condn.	Product (Isolated Yield)	
				
1	**1b** (R^1 = F)	A	**2b** (68%)	**3b** (3%)
2		B	**2b** (22%)	**3b** (67%)
3	**1c** (R^1 = Cl)	A	**2c** (64%)	**3c** (trace)
4		B	**2c** (13%)	**3c** (79%)
5	**1d** (R^1 = Br)	A	**2d** (62%)	**3d** (6%)
6		B	**2d** (11%)	**3d** (82%)
7	**1e** (R^1 = Me)	A	**2e** (77%)	**3e** (3%)
8		B	**2e** (6%)	**3e** (77%)
9	**1f** (R^1 = OMe)	A	**2f** (75%)	**3f** (5%)
10		B	**2f** (16%)	**3f** (65%)
11	**1g** (R^1 = CN)	A[a]	**2g** (17%)	**3g** (0%)
12		B	**2g** (5%)	**3g** (0%)

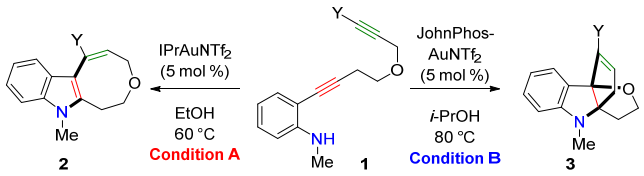
				
13	**1h**	A	**2h** (0%)	**3h** (0%)
14		B	**2h** (0%)	**3h** (44%)
				
15	**1i**	A	**2i** (64%)	**3i** (<19%[b])
16		B	**2i** (6%)	**3i** (79%)
				
17	**1j**	A	**2j** (71%)	**3j** (trace)
18		B	**2j** (9%)	**3j** (80%)

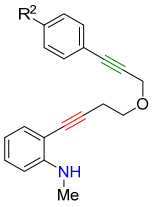
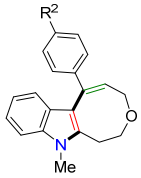
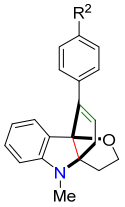
[a] The second portion of $IPrAuNTf_2$ (5 mol %) was added after the reaction mixture was stirred for 6.5 h. [b] Containing small amounts of impurities.

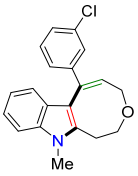
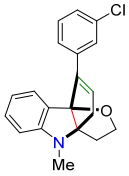
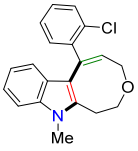
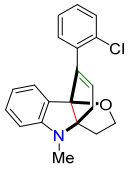
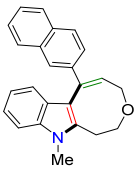
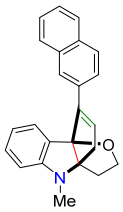
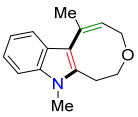
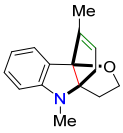
Next, the substrate scope at the terminal phenyl ring was explored (Table 3). Electron-withdrawing halogen (Br, Cl) and cyano substituents at the *p*-position on the phenyl rings were tolerated by both conditions (**2k**: 73%, **2l**: 56% and **2m**: 73% under condition A, and **3k**: 77%, **3l**: 69% and **3m**: 74% under condition B). The reactions of **1n** or **1o** bearing an electron-donating groups (Me or MeO) at the *p*-position gave the corresponding fused indoles **2n** and **2o** in moderate or low yields using condition A (53% and 22%[11], respectively, entries 7 and 9).[8] In contrast, the reaction of **1n** and **1o** under condition B gave the desired indolines **3n** and **3o**, respectively, in good yields (76% and 67%, entries 8 and 10). The evaluation of the substitution position on the phenyl ring was performed using Cl-substituted derivatives. The *m*-chloro derivative **1p** underwent the desired reaction to afford the corresponding **2p** and **3p** in good yields (entries 11 and 12). The

o-Cl derivative **1q** showed good reactivity to afford the fused indole **2q** in 70% yield, whereas condition B was less efficient, resulting in a lower yield of **2q** (27%) and selectivity (**2q**:**3q** = *ca.* 1:1; entry 14). The aniline **1r** bearing a naphth-2-yl group instead of a phenyl group provided the desired products **2r** and **3r** in 63% and 52% yields, respectively (entries 15 and 16). In contrast, the aniline **1s** bearing a methyl group at the alkyne terminus displayed low reactivity in the formation of **2s** and **3s** (entries 17 and 18). In this case, using DCE as the solvent, afforded the propellane-type indoline **3s** in good yield (82%, entry 19).

Table 3. Substrate scope (2).



Entry	Substrate (R^2)	Condn.	Product (Isolated Yield)	
				
1	**1k** (R^2 = Cl)	A	**2k** (73%)	**3k** (<10%[a])
2		B	**2k** (8%)	**3k** (77%)
3	**1l** (R^2 = Br)	A	**2l** (56%)	**3l** (<15%[a])
4		B	**2l** (4%)	**3l** (69%)
5	**1m** (R^2 = CN)	A	**2m** (73%)	**3m** (<11%[a])
6		B	**2m** (6%)	**3m** (74%)
7	**1n** (R^2 = Me)	A[b]	**2n** (53%)	**3n** (12%)
8		B	**2n** (10%)	**3n** (76%)
9	**1o**	A[b]	**2o** (22%)	**3o** (<14%[a])

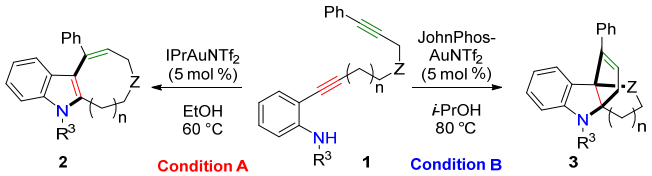
10	(R^2 = OMe)	B	**2o** (0%)	**3o** (67%)
				
11		A	**2p** (71%)	**3p** (<7%[a])
12	**1p**	B	**2p** (8%)	**3p** (74%)
				
13		A	**2q** (70%)	**3q** (<12%[a])
14	**1q**	B	**2q** (27%)	**3q** (26%)
				
15		A	**2r** (63%)	**3r** (<9%[a])
16	**1r**	B	**2r** (0%)	**3r** (52%)
				
17		A[c]	**2s** (16%)	**3s** (8%)
18	**1s**	B	**2s** (5%)	**3s** (34%)
19		C[d]	**2s** (trace)	**3s** (82%)

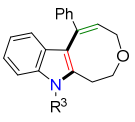
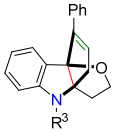
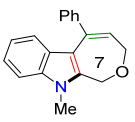
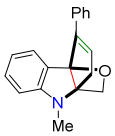
[a] Containing small amounts of impurities. [b] The second portion of $IPrAuNTf_2$ (5 mol %) was added after the reaction mixture was stirred for 1 h. [c] The reaction was carried out in *i*-PrOH using $IPrAuNTf_2$ (5 mol %) and MS3Å at 80 °C. [d] The reaction was carried out under entry 6 of Table 1.

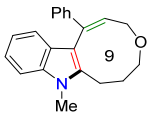
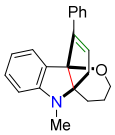
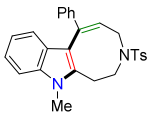
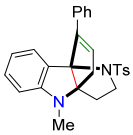
We next examined the reaction of substrates bearing a variety of functional groups on anilines and linker moieties (Table 4). The use of unprotected aniline derivative **1t** provided the desired

products **2t** and **3t** in low yields under respective conditions (entries 1 and 2). Changing the methyl group to a benzyl group did not affect the cascade reaction (entries 3 and 4). When using **1v** bearing a shorter carbon tether (n = 0), the seven-membered ring-fused indole **2v** was obtained in 63% yield (condition A) and 44% yield (condition B). However, no propellane-type indoline **3v** was observed under both conditions (entries 5 and 6), presumably because of the ring strain in **3v**. The use of **1w** bearing a longer carbon tether (n = 2) did not afford the nine-membered ring-fused indoles **2w**; however, the propellane-type indoline **3w** was produced under condition B but in low yield (28%, entry 8). In sharp contrast, treatment of sulfonamide **1x** under conditions A and B produced only the ring-fused indole **2x** (63% and 67%, respectively) without producing the propellane-type indoline **3x** (entries 9 and 10).

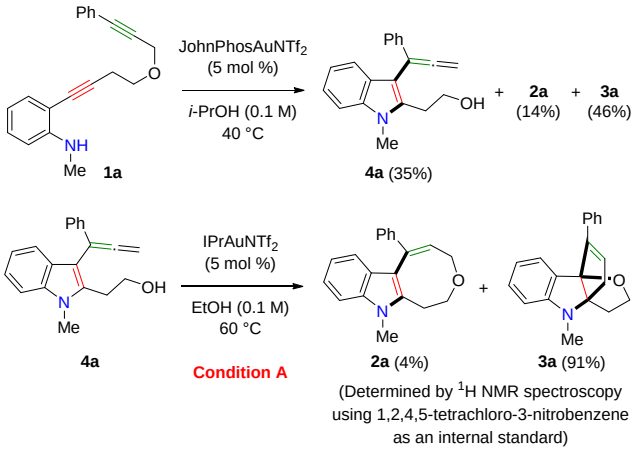
Table 4. Substrate scope (3).



Entry	Substrate (R^3, n, Z)	Condn.	Product (Isolated Yield)	
				
1	**1t** (H, 1, O)	A	**2t** (32%)	**3t** (7%)
2		B	**2t** (0%)	**3t** (18%)
3	**1u** (Bn, 1, O)	A	**2u** (56%)	**3u** (trace)
4		B	**2u** (8%)	**3u** (77%)
				
5	**1v**	A	**2v** (63%)	**3v** (0%)

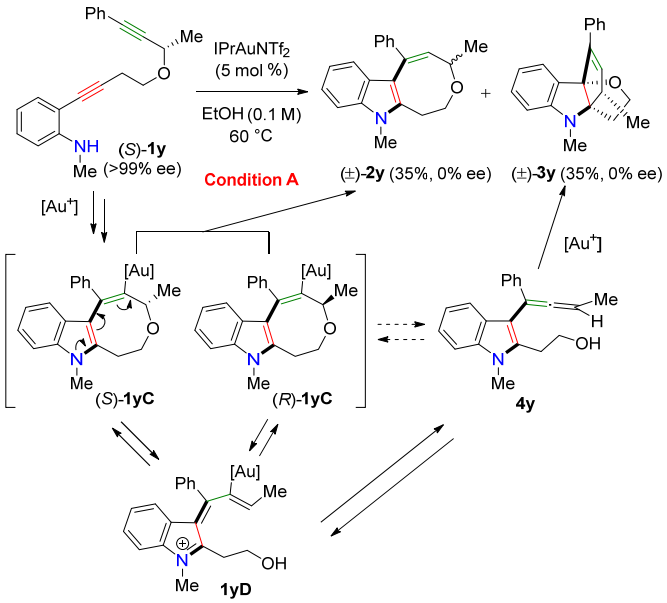
6	(Me, 0, O)	B	**2v** (44%)	**3v** (0%)
				
7	**1w** (Me, 2, O)	A	**2w** (0%)	**3w** (0%)
8		B	**2w** (0%)	**3w** (28%)
				
9	**1x** (Me, 1, NTs)	A	**2x** (63%)	**3x** (0%)
10		B	**2x** (67%)	**3x** (0%)

We conducted several experiments to gain insight into the mechanism of the cascade reaction (Scheme 2). Initially, the cascade reaction was performed at lower temperature (40 °C), which resulted in the production of an allene **4a** as a plausible intermediate, along with the fused indole **2a** and indoline **3a**. Interestingly, allene **4a** subjected to condition A (favoring the formation of the oxocine-fused indoles **2**) afforded **2a** (4%) and **3a** (91%).[9] These results strongly indicated that the allene **4a** is the intermediate of the propellane-type indoline **3a** and not the oxocine-fused indole **2a**.



Scheme 2. Gold-catalyzed cyclization of **1a**.

Next, an optically active **1y** with a methyl group at the propargylic position was prepared. We first expected that the cascade reaction of **1y** would give the corresponding optically active oxocine-fused indole **2y** as a single enantiomer, via 5-*endo*-*dig* hydroamination and 8-*endo*-*dig* cycloisomerization followed by protodeauration of **1yC** (Scheme 3). Quite surprisingly, the reaction of (*S*)-**1y** under condition A provided the fused indole **2y** (35% yield) and the indoline **3y** (35% yield) with complete loss of optical activity [The reaction of (*S*)-**1y** under condition B gave the oxocine-fused indole **2y** (<31 %, 0 % ee) without providing propellane-type indoline **3y**][12]. Additionally, the reaction of **1y** was conducted with the shorter reaction time or the lower reaction temperature to give the corresponding allene intermediates **4y**, whose optical activities were also lost completely.[13] These results suggested that the catalytic cycle involves the formation of an achiral cationic intermediate such as **1yD**, resulting from the ring-opening reaction of vinyl-gold intermediate **1yC**.[7b] Formation of racemic **2y** and **3y** is rationalized by gold-catalyzed cyclization of the vinyl-gold derivative **1yD**. However, racemization of the optically active allene **4y** by the action of the gold catalyst cannot be ruled out.[14]

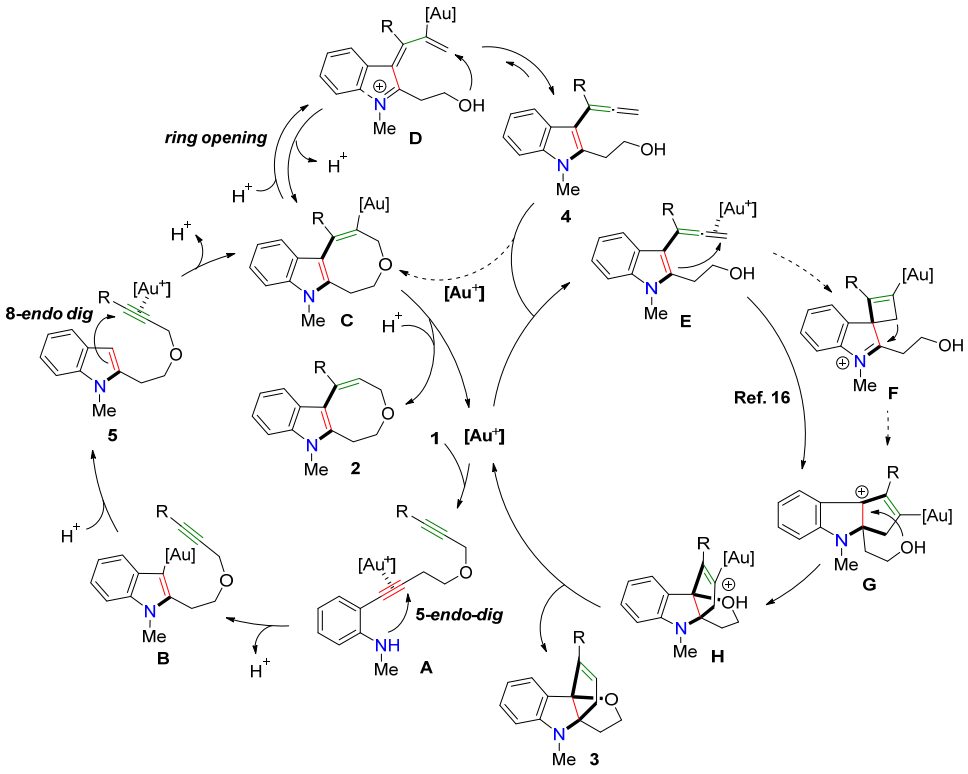


Scheme 3. Gold-catalyzed cyclization of **1y**.

On the basis of these experiments, a proposed reaction mechanism is shown in Scheme 4. As reported in our previous work,[8] activation of the alkyne by cationic gold, as depicted in **A**, promotes 5-*endo-dig* cyclization followed by protodeauration to give the indole **5**. Subsequently, the activation of the second alkyne leads to the 8-*endo-dig* hydroarylation of **5** to form a vinyl-gold intermediate **C**. The eight-membered ring of intermediate **C** is easily opened to generate a cationic intermediate **D**, which could return to **C** by nucleophilic attack of the hydroxy group to the highly reactive conjugated diene. Intermediate **C** undergoes protodeauration to generate the oxocine-fused indole **2**. Alternatively, elimination of gold from intermediate **D** may occur to provide allene **4**,[15] which is converted to the propellane-type indoline **3**, as we reported previously.[9] The reverse reaction of allene **4** to vinyl-gold **C** should be much slower than formation of **G** because the reaction of **4a** produced only a small amount of **2a** under condition A (4%, Scheme 2). Noteworthy, Bi et al. have computationally demonstrated that direct formation of the cationic

intermediate **G** from **E** by reaction at the indole 2 position is favored over the ring expansion pathway through the four-membered ring **F**.[16]

The significant effects of the reaction solvent and ligand can be partly rationalized as follows: protic solvents such as alcohol promote protodeauration of vinyl-gold intermediate **C**, thus contributing to the formation of oxocine-fused indoles (Table 1, entries 2–5). Electron-donating ligands such as IPr ligands are also known to accelerate protodeauration,[17] resulting in the predominant formation of the fused indoles. However, further investigation is necessary to elucidate the effects of the ligand.



Scheme 4. Proposed reaction mechanism.

CONCLUSION

In conclusion, we have developed controllable formation of eight-membered ring-fused indoles and propellane-type indolines via gold-catalyzed cascade cyclization. This reaction gives quick access to various ring-fused indoles and indolines from simple aniline derivatives, depending on the ligands or solvents employed. Examination with an aniline derivative bearing a chiral center demonstrated that these types of cascade cyclization reactions proceed via the ring-opened intermediate **D**. Further studies including an investigation of the exact reaction mechanism and application to the synthesis of biologically-active compounds are now in progress.

EXPERIMENTAL SECTION

General Methods. ^{1}H NMR spectra were recorded using a JEOL ECA-500 spectrometer at 500 MHz frequency. Chemical shifts are reported in δ (ppm) relative to Me_4Si [in $CDCl_3$ or DMSO] as internal standard. ^{13}C NMR spectra were recorded using a JEOL ECA-500 and a JNM ECZ600R, and referenced to the residual solvent signal. IR spectra were obtained on a JASCO FT/IR-4100 spectrometer. Exact mass (HRMS) spectra were recorded on a Shimadzu LC-ESI-IT-TOF-MS equipment (ESI). Column chromatography was performed using a forced flow (flash chromatography) of the indicated solvent system on Wakogel C-300E (Wako), Chromatorex NH-DM1020 (Fuji Silysia) or Biotage Isolera flash purification system on Presep® Silica Gel Type M (Wako), Presep® Silica Gel Type L (Wako) or Biotage ZIP® ISOLUTE NH (Biotage). All the heating experiments were performed in an oil bath. The Compounds **S1b**, **S1c**, **S1g**, **S1i**, **S1j**, **S3a**, **S3b**, **S3c** are commercially available. The known Compounds **S1h**[18], **S1j**[19], **S2a**[20], **S2d**[9], **S2e**[9], **S2f**[9], **S2k**[9], **S3d**[21], **S4**[22], **S5f**[23], **S5g**[24], **S6**[25] were synthesized according to the literatures. The ^{1}H NMR spectra of **S2c**[26], **S2g**[27] and **S5b**[28] were in good accordance with those reported in literature.

Structures of **S1a**, **S1b**, **S1c**, **S1g**, **S1h**, **S1i**, **S1j**, **S2a-S2j**, **S3a-S3d**, **S4**, **S5a-S5e**, **S6**, **S7**, **S8** are shown in Schemes S1-S5.

Preparation of the Cyclization Precursor.

4-Fluoro-2-iodo-*N*-methylaniline (S2b). To a stirred solution of 4-fluoro-2-iodoaniline (**S1b**) (1.16 g, 4.90 mmol) in THF (16 mL) was added MeLi (1.16 M in Et_2O; 4.65 mL, 5.39 mmol) at –78 °C under argon. After the mixture was stirred for 1 h at this temperature, MeI (0.366 mL, 5.89 mmol) was added to the mixture. The mixture was gradually warmed to room temperature and stirred for 12 h at this temperature. The reaction was quenched with saturated aqueous NH_4Cl. The resulting mixture was extracted with EtOAc twice. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/EtOAc = 40/1) to give **S2b** (630 mg, 51%) as a red oil; IR (neat cm^{-1}): 3408 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.83 (s, 3H), 3.95-4.04 (br m, 1H), 6.45 (dd, J = 8.9, 4.9 Hz, 1H), 6.98 (ddd, J = 8.9, 8.9, 2.9 Hz, 1H), 7.40 (dd, J = 8.0, 2.9 Hz, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 31.5, 83.4 (d, $J_{C\text{-}F}$ = 8.4 Hz), 109.5 (d, $J_{C\text{-}F}$ = 7.2 Hz), 115.8 (d, $J_{C\text{-}F}$ = 21.6 Hz), 125.3 (d, $J_{C\text{-}F}$ = 25.2 Hz), 145.1 (d, $J_{C\text{-}F}$ = 2.4 Hz), 154.5 (d, $J_{C\text{-}F}$ = 238.7 Hz); HRMS (ESI-TOF) m/z: $[M + H]^+$ calcd for C_7H_7FIN 251.9680; found 251.9679.

4-Chloro-2-iodo-*N*-methylaniline (S2c). According to the procedure described for the preparation of **S2b**, 4-chloro-2-iodoaniline (**S1c**) (991 mg, 3.91 mmol) was converted into **S2c** (271 mg, 26%) by the reaction with MeLi (1.16 M in Et_2O; 4.05 mL, 4.69 mmol) and MeI (292 μL, 4.69 mmol) in THF (6.5 mL) at –78 °C to room temperature for 5 h. Column chromatography: silica gel (gradient 1% to 5% EtOAc in hexane); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.87 (d, J = 5.2

Hz, 3H), 4.15-4.24 (br m, 1H), 6.45 (d, *J* = 8.6 Hz, 1H), 7.20 (dd, *J* = 8.6, 2.3 Hz, 1H), 7.62 (d, *J* = 2.3 Hz, 1H). The ^{1}H NMR spectra was in good agreement with that reported.[26]

3-Iodo-4-(methylamino)benzonitrile (S2g). According to the procedure described for the preparation of **S2b**, 4-amino-3-iodobenzonitrile (**S1g**) (452 mg, 1.85 mmol) was converted into **S2g** (210 mg, 44%) by the reaction with MeLi (1.16 M in Et_2O; 1.91 mL, 2.22 mmol) and MeI (150 μL, 2.41 mmol) in THF (6.2 mL) at –78 °C to room temperature for 1 h. Column chromatography: silica gel (hexane/EtOAc = 10/1); ^{1}H NMR (400 MHz, $CDCl_3$) δ: 2.94 (d, *J* = 5.2 Hz, 3H), 4.76-4.85 (br m, 1H), 6.49 (d, *J* = 8.6 Hz, 1H), 7.48 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.88 (d, *J* = 1.7 Hz, 1H). The ^{1}H NMR spectra was in good agreement with that reported.[27]

3-Bromo-2-iodo-*N*-methylaniline (S2h). According to the procedure described for the preparation of **S2b**, 3-bromo-2-iodoaniline (**S1h**) (244 mg, 0.818 mmol) was converted into **S2h** (78.9 mg, 31%) by the reaction with MeLi (1.16 M in Et_2O; 0.847 mL, 0.982 mmol) and MeI (65.9 μL, 1.06 mmol) in THF (2.7 mL) at –78 °C to room temperature for 10 h. Column chromatography: (gradient 1% to 5% EtOAc in hexane) and amine silica gel (hexane only); colorless oil; IR (neat cm^{-1}): 3401 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.88 (d, *J* = 5.2 Hz, 3H), 4.47-4.58 (br m, 1H), 6.43 (d, *J* = 8.0 Hz, 1H), 7.00 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.10 (dd, *J* = 8.0, 8.0 Hz, 1H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 31.4, 92.0, 107.7, 120.8, 130.1, 130.5, 150.6; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for C_7H_8BrIN 311.8879; found 311.8874.

5-Bromo-2-iodo-*N*-methylaniline (S2i). According to the procedure described for the preparation of **S2b**, 5-bromo-2-iodoaniline (**S1i**) (473 mg, 1.59 mmol) was converted into **S2i** (335 mg, 68%) by the reaction with MeLi (1.16 M in Et_2O; 1.64 mL, 1.91 mmol) and MeI (129 μL, 2.06 mmol) in THF (5.3 mL) at –78 °C to room temperature for 10 h. Column chromatography:

(gradient 1% to 5% EtOAc in hexane); yellow solid; mp 78-80 °C; IR (neat cm^{-1}): 3401 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.87 (d, *J* = 5.2 Hz, 3H), 4.23-4.29 (br m, 1H), 6.57 (dd, *J* = 8.6, 2.3 Hz, 1H), 6.64 (d, *J* = 2.3 Hz, 1H), 7.46 (d, *J* = 8.6 Hz, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 30.8, 82.7, 112.7, 121.1, 123.7, 139.6, 149.2; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for C_7H_8BrIN 311.8879; found 311.8880.

[3-(But-3-yn-1-yloxy)prop-1-yn-1-yl]benzene (S5a). To a suspension of NaH (532 mg, 13.3 mmol) in anhydrous THF (15 mL) at 0 °C was added dropwise 3-butyn-1-ol (**S3a**) (777 mg, 11.1 mmol). After the mixture was stirred for 30 min, a solution of (3-bromoprop-1-yn-1-yl)benzene (**S4**) (2.38 g, 12.2 mmol) in THF (3.5 mL) was added to the reaction mixture at 0 °C. The mixture was stirred at room temperature for additional 7.5 h, and then diluted with water. The resulting mixture was extracted with EtOAc twice. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (gradient 1% to 5% EtOAc in hexane) to give **S5a** (1.46 g, 73%) as a yellow oil; IR (neat cm^{-1}): 2235 (C≡C); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.02 (t, *J* = 2.9 Hz, 1H), 2.54 (td, *J* = 6.9, 2.9 Hz, 2H), 3.73 (t, *J* = 6.9 Hz, 2H), 4.43 (s, 2H), 7.28-7.34 (m, 3H), 7.43-7.47 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 19.7, 58.9, 67.9, 69.4, 81.0, 84.7, 86.4, 122.5, 128.3 (2C), 128.5, 131.7 (2C); HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{13}H_{12}NaO$ 207.0780; found 207.0779.

[3-(Prop-2-yn-1-yloxy)prop-1-yn-1-yl]benzene (S5b). According to the procedure described for the preparation of **S5a**, pent-4-yn-1-ol (**S3b**) (0.135 mL, 2.29 mmol) was converted into **S5b** (155 mg, 40%) by the reaction with **S4** (491 mg, 2.52 mmol) in THF (1.3 mL), NaH (82.3 mg, 3.43 mmol) in THF (2.5 mL) at room temperature for 5 h. Column chromatography: silica gel

(gradient 1% to 3% EtOAc in hexane); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.48 (t, *J* = 2.4 Hz, 1H), 4.33 (d, *J* = 2.4 Hz, 2H), 4.50 (s, 2H), 7.30-7.50 (m, 5H). The ^{1}H NMR spectra was in good agreement with that reported.[28]

[3-(Hex-5-yn-1-yloxy)prop-1-yn-1-yl]benzene (S5c). According to the procedure described for the preparation of **S5a**, pent-4-yn-1-ol (**S3c**) (0.221 mL, 2.38 mmol) was converted into **S5c** (382 mg, 81%) by the reaction with **S4** (464 mg, 2.38 mmol) in THF (1.0 mL), NaH (105 mg, 2.62 mmol) in THF (2.0 mL) at room temperature for 6.5 h. Column chromatography: silica gel (gradient 1% to 5% EtOAc in hexane); yellow oil; IR (neat cm^{-1}): 2335 (C≡C); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.85 (tt, *J* = 6.3, 6.3 Hz, 2H), 1.95 (t, *J* = 2.6 Hz, 1H), 2.33 (td, *J* = 6.3, 2.6 Hz, 2H), 3.69 (t, *J* = 6.3 Hz, 2H), 4.37 (s, 2H), 7.28-7.33 (m, 3H), 7.42-7.47 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 15.2, 28.5, 58.9, 68.4, 68.5, 83.8, 85.2, 86.1, 122.6, 128.2 (2C), 128.4, 131.7 (2C); HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{14}H_{15}O$ 199.1117; found 199.1118.

***N*-(But-3-yn-1-yl)-4-methyl-*N*-(3-phenylprop-2-yn-1-yl)benzenesulfonamide (S5d).** A mixture of *N*-(but-3-yn-1-yl)-4-methylbenzenesulfonamide (**S3d**) (185 mg, 0.829 mmol) and K_2CO_3 (229 mg, 1.66 mmol) in dry MeCN (6.0 mL) was added **S4** (178 mg, 0.911 mmol) in dry MeCN (2.3 mL) at room temperature. The mixture was stirred under reflux for 2 h, and then diluted with water. The resulting mixture was extracted with EtOAc twice. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (gradient 6% to 19% EtOAc in hexane) to give **S5d** (261 mg, 93%) as a white solid; mp 84-85 °C; IR (neat cm^{-1}): 2253 (C≡C), 1160 (S=O), 1348 (S=O); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.03 (t, *J* = 2.6 Hz, 1H), 2.34 (s, 3H), 2.57 (td, *J* = 7.4, 2.6 Hz, 2H), 3.44 (t, *J* = 7.4 Hz, 2H), 4.42 (s, 2H), 7.09 (d, *J* = 8.6 Hz, 2H), 7.22-7.30 (m, 5H), 7.78

(d, J = 8.6 Hz, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 19.0, 21.4, 38.1, 45.5, 70.3, 80.8, 81.7, 85.6, 121.9, 127.6 (2C), 128.1 (2C), 128.5, 129.5 (2C), 131.4 (2C), 135.7, 143.6; HRMS (ESI-TOF) m/z: $[M + H]^+$ calcd for $C_{20}H_{19}NO_2S$ 338.1209; found 338.1205.

(*S*)-[3-(But-3-yn-1-yloxy)but-1-yn-1-yl]benzene (S5e). To a suspension of NaH (651 mg, 16.3 mmol) in anhydrous THF (16 mL) at 0 °C was added dropwise a solution of (*S*)-4-phenylbut-3-yn-2-ol (**S6**) (1.83 g, 12.5 mmol) in THF (4.9 mL). After the mixture was stirred for 30 min, 3-bromopropan-1-ol (2.09 g, 15.0 mmol) was added to the reaction mixture at 0 °C. The mixture was stirred at room temperature for additional 7 h, and then diluted with water. The resulting mixture was extracted with EtOAc twice. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (gradient 5% to 30% EtOAc in hexane) to give **S7** (1.14 g, <45%), including inseparable impurities, as a yellow oil. To a solution of **S7** (1.14 g, *ca*. 7.80 mmol) including impurities in CH_2Cl_2 (7.8 mL) were added TEMPO (122 mg, 0.78 mmol) and DAIB (2.77 g, 8.59 mmol) at room temperature. After being stirred for 2 h, the mixture was washed with a saturated aqueous solution of $Na_2S_2O_3$ and extracted with CH_2Cl_2 twice. The combined organic extracts were washed with aqueous $NaHCO_3$ and brine, dried over Na_2SO_4, filtered, and concentrated in vacuo to give crude **S8** as a red oil. To a solution of crude **S8** in MeOH (9.8 mL) were added Bestmann Reagent (1.65 g, 8.59 mmol) and K_2CO_3 (1.29 g, 9.37 mmol) at 0 °C. The mixture was warmed to room temperature and stirred for 2 h. The reaction was quenched with saturated aqueous NH_4Cl. The resulting mixture was extracted with EtOAc twice. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (gradient 2% to 5% EtOAc in hexane) to give **S5e** (352 mg, 23%, 2 steps) as a colorless oil; $[\alpha]^{25}_D$ –150.0 (*c* 1.24, $CHCl_3$); IR (neat cm^{-1}): 2249

(C≡C); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.52 (d, *J* = 6.7 Hz, 3H), 2.00 (t, *J* = 2.7 Hz, 1H), 2.52 (ddd, *J* = 7.0, 7.0, 2.7 Hz, 2H), 3.60 (dt, *J* = 12.6, 7.0 Hz, 1H), 3.90 (dt, *J* = 12.6, 7.0 Hz, 1H), 4.43 (q, *J* = 6.7 Hz, 1H), 7.27-7.32 (m, 3H), 7.41-7.46 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 19.8, 22.0, 65.8, 66.6, 69.3, 81.1, 85.0, 88.7, 122.5, 128.2 (2C), 128.3, 131.6 (2C); HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{14}H_{15}O$ 199.1117; found 199.1123.

***N*-Methyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1a).** A mixture of 2-iodo-*N*-methylaniline (**S2a**) (1.43 g, 6.1 mmol), **S5a** (1.24 g, 6.7 mmol), $PdCl_2(PPh_3)_2$ (216 mg, 0.3 mmol), CuI (58.0 mg, 0.3 mmol), and Et_3N (2.7 mL, 18 mmol) in DMF (20 mL) was stirred at room temperature under Ar for 11 h. The mixture was diluted with saturated aqueous NH_4Cl. The resulting mixture was extracted with EtOAc twice. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (hexane/acetone = 20/1) to give **1a** (1.03 g, 58%) as a purple oil; IR (neat cm^{-1}): 3297 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.82 (t, *J* = 6.9 Hz, 2H), 2.87 (d, *J* = 5.2 Hz, 3H), 3.82 (t, *J* = 6.9 Hz, 2H), 4.46 (s, 2H), 4.69-4.74 (br m, 1H), 6.55 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.18 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.24 (d, *J* = 8.0 Hz, 1H), 7.28-7.34 (m, 3H), 7.43-7.47 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.2, 58.9, 68.3, 78.4, 84.9, 86.4, 92.2, 107.7, 108.7, 115.9, 122.5, 128.3 (2C), 128.5, 129.4, 131.7 (3C), 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{20}NO$ 290.1539; found 290.1540.

4-Fluoro-*N*-methyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1b). According to the procedure described for the preparation of **1a**, 4-fluoro-2-iodo-*N*-methylaniline (**S2b**) (293 mg, 1.17 mmol) was converted into **1b** (247 mg, 69%) by the reaction with **S5a** (236 mg, 1.28 mmol), $PdCl_2(PPh_3)_2$ (40.9 mg, 0.0583 mmol), CuI (11.1 mg, 0.0583 mmol) and Et_3N (0.51 mL) in DMF (3.9 mL) at room temperature for 6 h. Column chromatography: silica gel

(hexane/acetone = 20/1) : yellow oil; IR (neat cm^{-1}): 3422 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.82 (t, *J* = 6.9 Hz, 2H), 2.85 (d, *J* = 5.2 Hz, 3H), 3.82 (t, *J* = 6.9 Hz, 2H), 4.46 (s, 2H), 4.52-4.59 (br m, 1H), 6.45 (dd, *J* = 8.9, 4.9 Hz, 1H), 6.91 (ddd, *J* = 8.9, 8.9, 2.9 Hz, 1H), 6.97 (dd, *J* = 8.9, 2.9 Hz, 1H), 7.28-7.35 (m, 3H), 7.43-7.47 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 20.9, 30.7, 59.0, 68.1, 77.5, 84.7, 86.5, 93.2, 108.2 (d, J_{C-F} = 9.6 Hz), 109.3 (d, J_{C-F} = 8.4 Hz), 116.1 (d, J_{C-F} = 22.8 Hz), 117.9 (d, J_{C-F} = 22.8 Hz), 122.4, 128.3 (2C), 128.5, 131.7 (2C), 146.8, 154.2 (d, J_{C-F} = 233.9 Hz); HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}FNO$ 308.1445; found 308.1450.

4-Chloro-*N*-methyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1c). According to the procedure described for the preparation of **1a**, 4-chloro-2-iodo-*N*-methylaniline (**S2c**) (259 mg, 0.966 mmol) was converted into **1c** (218 mg, 41%) by the reaction with **S5a** (192 mg, 1.06 mmol), $PdCl_2(PPh_3)_2$ (33.9 mg, 0.0483 mmol), CuI (9.20 mg, 0.0483 mmol) and Et_3N (0.42 mL) in DMF (3.2 mL) at room temperature for 5 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3410 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.81 (t, *J* = 6.9 Hz, 2H), 2.84 (d, *J* = 5.2 Hz, 3H), 3.81 (t, *J* = 6.9 Hz, 2H), 4.46 (s, 2H), 4.69-4.74 (br m, 1H), 6.45 (d, *J* = 8.6 Hz, 1H), 7.12 (dd, *J* = 8.6, 2.3 Hz, 1H), 7.20 (d, *J* = 2.3 Hz, 1H), 7.28-7.34 (m, 3H), 7.43-7.46 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.3, 59.0, 68.1, 77.3, 84.7, 86.5, 93.4, 109.0, 109.7, 120.2, 122.4, 128.3 (2C), 128.5, 129.2, 131.0, 131.7 (2C), 148.6; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{20}H_{18}ClNNaO$ 346.0969; found 346.0966.

4-Bromo-*N*-methyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1d). According to the procedure described for the preparation of **1a**, 4-bromo-2-iodo-*N*-methylaniline (**S2d**) (195 mg, 0.624 mmol) was converted into **1d** (159 mg, 69%) by the reaction with **S5a** (127 mg, 0.687 mmol), $PdCl_2(PPh_3)_2$ (21.9 mg, 0.0312 mmol), CuI (5.94 mg, 0.0312 mmol) and Et_3N

(0.27 mL) in DMF (2.1 mL) at room temperature for 7 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3414 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.81 (t, *J* = 6.6 Hz, 2H), 2.84 (d, *J* = 5.2 Hz, 3H), 3.81 (t, *J* = 6.6 Hz, 2H), 4.46 (s, 2H), 4.70-4.76 (br m, 1H), 6.41 (d, *J* = 8.6 Hz, 1H), 7.23-7.26 (m, 1H), 7.28-7.35 (m, 4H), 7.43-7.46 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.2, 59.0, 68.1, 77.2, 84.7, 86.5, 93.6, 106.9, 109.5 110.2, 122.4, 128.3 (2C), 128.5, 131.7 (2C), 132.1, 133.8, 149.0; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{20}H_{18}BrNNaO$ 390.0464; found 390.0461.

***N*,4-Dimethyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1e).** According to the procedure described for the preparation of **1a**, 2-iodo-*N*,4-dimethylaniline (**S2e**) (260 mg, 1.05 mmol) was converted into **1e** (185 mg, 58%) by the reaction with **S5a** (213 mg, 1.16 mmol), $PdCl_2(PPh_3)_2$ (37.0 mg, 0.0527 mmol), CuI (10.0 mg, 0.0527 mmol) and Et_3N (0.46 mL) in DMF (3.5 mL) at room temperature for 9 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3407 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.19 (s, 3H), 2.81 (t, *J* = 6.9 Hz, 2H), 2.85 (d, *J* = 4.0 Hz, 3H), 3.82 (t, *J* = 6.9 Hz, 2H), 4.46 (s, 2H), 4.51-4.56 (br m, 1H), 6.48 (d, *J* = 8.0 Hz, 1H), 7.00 (d, *J* = 8.0 Hz, 1H), 7.08 (s, 1H), 7.28-7.35 (m, 3H), 7.44-7.47 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 20.1, 21.0, 30.5, 59.0, 68.3, 78.5, 84.8, 86.4, 91.8, 107.6, 108.9, 122.5, 125.0, 128.2 (2C), 128.5, 130.0, 131.7 (2C), 132.1, 147.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1694.

4-Methoxy-*N*-methyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1f). According to the procedure described for the preparation of **1a**, 2-bromo-4-methoxy-*N*-methylaniline (**S2f**) (365 mg, 1.69 mmol) was converted into **1f** (92.1 mg, 17%) by the reaction with **S5a** (335 mg, 1.86 mmol), $PdCl_2(PPh_3)_2$ (59.2 mg, 0.0843 mmol), CuI (16.1 mg, 0.0843 mmol) and Et_3N (0.74 mL) in DMF (5.6 mL) at 80 °C for 5 h. Column chromatography: silica gel

(hexane/acetone = 20/1 and gradient 2% to 15% EtOAc in hexane): blue oil; IR (neat cm^{-1}): 3407 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.82 (t, *J* = 6.6 Hz, 2H), 2.84 (s, 3H), 3.72 (s, 3H), 3.82 (t, *J* = 6.6 Hz, 2H), 4.37-4.40 (br m, 1H), 4.46 (s, 2H), 6.51 (d, *J* = 8.6 Hz, 1H), 6.82 (dd, *J* = 8.6, 2.9 Hz, 1H), 6.86 (d, *J* = 2.9 Hz, 1H), 7.28-7.34 (m, 3H), 7.43-7.47 (m, 2H); $^{13}C\{^{1}H\}$NMR (125 MHz, $CDCl_3$) δ: 21.0, 31.0, 55.9, 59.0, 68.2, 78.3, 84.8, 86.4, 92.3, 108.3, 110.1, 116.3, 116.8, 122.5, 128.3 (2C), 128.5, 131.8 (2C), 145.0, 150.6; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO_2$ 320.1645; found 320.1641.

4-(Methylamino)-3-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}benzonitrile (1g). According to the procedure described for the preparation of **1a**, 3-iodo-4-(methylamino)benzonitrile (**S2g**) (195 mg, 0.757 mmol) was converted into **1g** (199 mg, 84%) by the reaction with **S5a** (153 mg, 0.833 mmol), $PdCl_2(PPh_3)_2$ (26.6 mg, 0.0379 mmol), CuI (7.21 mg, 0.0379 mmol) and Et_3N (0.33 mL) in DMF (2.5 mL) at room temperature for 8 h. Column chromatography: silica gel (hexane/acetone = 20/1 and gradient 1% to 25% EtOAc in hexane): orange oil; IR (neat cm^{-1}): 3410 (NH), 2217 (C≡N); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.81 (t, *J* = 6.3 Hz, 2H), 2.90 (d, *J* = 5.2 Hz, 3H), 3.82 (t, *J* = 6.3 Hz, 2H), 4.46 (s, 2H), 5.34-5.39 (br m, 1H), 6.50 (d, *J* = 8.6 Hz, 1H), 7.28-7.34 (m, 3H), 7.41 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.42-7.45 (m, 2H), 7.47 (d, *J* = 1.7 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 20.9, 29.8, 59.0, 67.9, 76.3, 84.6, 86.6, 94.4, 97.6, 108.2, 108.3, 120.0, 122.3, 128.3 (2C), 128.6, 131.7 (2C), 133.4, 135.2, 152.5; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{21}H_{18}N_2NaO$ 337.1311; found 337.1304.

3-Bromo-*N*-methyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1h). According to the procedure described for the preparation of **1a**, **S2h** (163 mg, 0.524 mmol) was converted into **1h** (37.3 mg, 19%) by the reaction with **S5a** (106 mg, 0.576 mmol), $PdCl_2(PPh_3)_2$ (18.4 mg, 0.0262 mmol), CuI (4.99 mg, 0.0262 mmol) and Et_3N (0.23 mL) in DMF (1.7 mL) at

room temperature for 11 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3413 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.84-2.90 (m, 5H), 3.85 (t, *J* = 6.6 Hz, 2H), 4.48 (s, 2H), 4.94-5.00 (br m, 1H), 6.46 (d, *J* = 8.3 Hz, 1H), 6.84 (d, *J* = 8.3 Hz, 1H), 7.00 (dd, *J* = 8.3, 8.3 Hz, 1H), 7.28-7.35 (m, 3H), 7.42-7.47 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.2, 30.3, 59.0, 68.1, 77.5, 84.7, 86.5, 97.0, 107.1, 109.5, 119.4, 122.4, 125.2, 128.3 (2C), 128.5, 129.7, 131.7 (2C), 151.5; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0641.

5-Bromo-*N*-methyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1i). According to the procedure described for the preparation of **1a**, 5-bromo-2-iodo-*N*-methylaniline (**S2i**) (256 mg, 0.819 mmol) was converted into **1i** (216 mg, 71%) by the reaction with **S5a** (166 mg, 0.901 mmol), $PdCl_2(PPh_3)_2$ (28.8 mg, 0.0410 mmol), CuI (7.80 mg, 0.0410 mmol) and Et_3N (0.36 mL) in DMF (2.7 mL) at room temperature for 10 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3407 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.80 (t, *J* = 6.6 Hz, 2H), 2.85 (d, *J* = 5.2 Hz, 3H), 3.81 (t, *J* = 6.6 Hz, 2H), 4.46 (s, 2H), 4.78-4.83 (br m, 1H), 6.66 (d, *J* = 1.7 Hz, 1H), 6.70 (dd, *J* = 8.0, 1.7 Hz, 1H), 7.07 (d, *J* = 8.0 Hz, 1H), 7.29-7.34 (m, 3H), 7.42-7.46 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.1, 59.0, 68.1, 77.6, 84.7, 86.5, 93.3, 106.6, 111.6, 118.7, 122.4, 123.6, 128.3 (2C), 128.6, 131.7 (2C), 132.6, 150.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0643.

2-Bromo-*N*-methyl-6-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1j). According to the procedure described for the preparation of **S2h**, 2-bromo-6-iodoaniline (**S1j**) (543 mg, 1.82 mmol) was converted into **S2j** (170 mg, <30%) including impurities by the reaction with MeLi (1.09 M in Et_2O; 2.01 mL, 2.19 mmol) and MeI (147 μL, 2.37 mmol) in THF (6.1 mL) at –78 ℃ to room temperature for 2.5 h. Column chromatography: silica gel (gradient 1% to 5%

EtOAc in hexanes) and amine silica gel (hexane only); According to the procedure described for the preparation of **1a**, **S2j** (142 mg, *ca*. 0.425 mmol) including impurities was converted into **1j** (53.3 mg, *ca*. 32%) by the reaction with **S5a** (92.4 mg, 0.502 mmol), $PdCl_2(PPh_3)_2$ (16.0 mg, 0.0228 mmol), CuI (4.34 mg, 0.0228 mmol) and Et_3N (0.20 mL) in DMF (1.5 mL) at room temperature for 9 h. Column chromatography: silica gel (gradient 2% to 5% EtOAc in hexanes and gradient 1% to 3% EtOAc in hexane): yellow oil; IR (neat cm^{-1}): 3418 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.80 (t, *J* = 6.9 Hz, 2H), 3.16 (s, 3H), 3.81 (t, *J* = 6.9 Hz, 2H), 4.32-4.38 (br m, 1H), 4.44 (s, 2H), 6.57 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.25 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.29-7.33 (m, 3H), 7.37 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.43-7.46 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 34.6, 58.9, 68.0, 79.5, 84.8, 86.4, 91.8, 112.8, 113.3, 119.8, 122.5, 128.3 (2C), 128.5, 131.8 (2C), 132.8, 133.5, 148.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0638.

***N*-Methyl-2-(4-{[3-(trimethylsilyl)prop-2-yn-1-yl]oxy}but-1-yn-1-yl)aniline (S9).** A mixture of 2-iodo-*N*-methylaniline (**S2a**) (729 mg, 3.11 mmol), [3-(but-3-yn-1-yloxy)prop-1-yn-1-yl]trimethylsilane (**S5f**) (618 mg, 3.43 mmol), $PdCl_2(PPh_3)_2$ (109 mg, 0.156 mmol), CuI (29.7 mg, 0.156 mmol), and Et_3N (1.36 mL, 9.34 mmol) in DMF (10.4 mL) was stirred at room temperature under Ar for 13 h. The mixture was diluted with saturated aqueous NH_4Cl. The resulting mixture was extracted with EtOAc twice. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (gradient 2% to 5% EtOAc in hexane) to give **S9** (294 mg, 33%) as an orange oil: IR (neat cm^{-1}): 3410 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 0.19 (s, 9H), 2.78 (t, *J* = 6.9 Hz, 2H), 2.90 (d, *J* = 5.2 Hz, 3H), 3.74 (t, *J* = 6.9 Hz, 2H), 4.23 (s, 2H), 4.67-6.73 (br m, 1H), 6.56 (d, *J* = 7.7 Hz, 1H), 6.60 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.19 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.24 (d, *J* = 7.7 Hz, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: –0.27 (3C), 20.8, 30.2, 58.9, 68.2, 78.3, 91.5, 92.1, 101.1,

107.6, 108.6, 115.8, 129.3, 131.6, 149.9; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{17}H_{24}NNaOSi$ 308.1441; found 308.1434.

***N*-Methyl-2-[4-(prop-2-yn-1-yloxy)but-1-yn-1-yl]aniline (S10).** To a stirred mixture of **S9** (1.07 g, 3.74 mmol) in MeOH (7.5 mL) was added K_2CO_3 (517 mg, 1.07 mmol). After being stirred at room temperature for 30 min, the mixture was filtered. The filtrate was evaporated to dryness and the residue was purified by column chromatography on silica gel (gradient 2% to 5% EtOAc in hexane) to give **S10** (645 mg, 81%) as an orange oil: IR (neat cm^{-1}): 3401 (NH), 2248 (C≡C); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.47 (t, *J* = 2.3 Hz, 1H), 2.78 (t, *J* = 6.9 Hz, 2H), 2.89 (d, *J* = 5.2 Hz, 3H), 3.75 (t, *J* = 6.9 Hz, 2H), 4.23 (d, *J* = 2.3 Hz, 2H), 4.66-4.72 (br m, 1H), 6.56 (d, *J* = 7.7 Hz, 1H), 6.60 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.19 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.24 (d, *J* = 7.7 Hz, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 20.9, 30.3, 58.2, 68.3, 74.6, 78.3, 79.4, 92.1, 107.6, 108.7, 115.9, 129.4, 131.7, 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{14}H_{16}NO$ 214.1226; found 214.1222.

2-(4-{[3-(4-Chlorophenyl)prop-2-yn-1-yl]oxy}but-1-yn-1-yl)-*N*-methylaniline (1k). According to the procedure described for the preparation of **1a**, **S10** (127 mg, 0.595 mmol) was converted into **1k** (138 mg, 71%) by the reaction with 1-chloro-4-iodobenzene (156 mg, 0.655 mmol), $PdCl_2(PPh_3)_2$ (20.9 mg, 0.0298 mmol), CuI (5.67 mg, 0.0298 mmol) and Et_3N (0.26 mL) in DMF (1.9 mL) at room temperature for 7 h. Column chromatography: silica gel (gradient 2% to 10% EtOAc in hexane and hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3410 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.80 (t, *J* = 6.9 Hz, 2H), 2.85 (s, 3H), 3.79 (t, *J* = 6.9 Hz, 2H), 4.43 (s, 2H), 4.67-4.74 (br m, 1H), 6.52-6.56 (m, 1H), 6.56-6.61 (m, 1H), 7.16-7.20 (m, 1H), 7.22-7.28 (m, 3H), 7.34-7.38 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 20.9, 30.2, 58.8, 68.4, 78.4, 85.2,

85.8, 92.1, 107.6, 108.7, 115.9, 120.9, 128.6 (2C), 129.4, 131.7, 132.9 (2C), 134.5, 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{20}H_{18}ClNNaO$ 346.0969; found 346.0966.

2-(4-{[3-(4-Bromophenyl)prop-2-yn-1-yl]oxy}but-1-yn-1-yl)-*N*-methylaniline (1l). According to the procedure described for the preparation of **1a**, **S10** (101 mg, 0.475 mmol) was converted into **1l** (110 mg, 63%) by the reaction with 1-bromo-4-iodobenzene (148 mg, 0.523 mmol), $PdCl_2(PPh_3)_2$ (16.7 mg, 0.0238 mmol), CuI (4.53 mg, 0.0238 mmol) and Et_3N (0.21 mL) in DMF (1.6 mL) at room temperature for 3 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3405 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.81 (t, *J* = 6.9 Hz, 2H), 2.87 (d, *J* = 5.2 Hz, 3H), 3.80 (t, *J* = 6.9 Hz, 2H), 4.44 (s, 2H), 4.68-4.73 (br m, 1H), 6.55 (d, *J* = 8.6 Hz, 1H), 6.60 (dd, *J* = 8.6, 8.6 Hz, 1H), 7.19 (dd, *J* = 8.6, 8.6 Hz, 1H), 7.24 (d, *J* = 8.6 Hz, 1H), 7.30 (d, *J* = 8.3 Hz, 2H), 7.44 (d, *J* = 8.3 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.3, 58.9, 68.4, 78.4, 85.3, 86.0, 92.1, 107.6, 108.7, 115.9, 121.4, 122.8, 129.4, 131.6 (2C), 131.7, 133.2 (2C), 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{20}H_{18}BrNNaO$ 390.0464; found 390.0466.

4-[3-({4-[2-(Methylamino)phenyl]but-3-yn-1-yl}oxy)prop-1-yn-1-yl]benzonitrile (1m). According to the procedure described for the preparation of **1a**, **S10** (103 mg, 0.482 mmol) was converted into **1m** (127 mg, 84%) by the reaction with 4-iodobenzonitrile (121 mg, 0.530 mmol), $PdCl_2(PPh_3)_2$ (16.9 mg, 0.0241 mmol), CuI (4.59 mg, 0.0241 mmol) and Et_3N (0.21 mL) in DMF (1.6 mL) at room temperature for 9 h. Column chromatography: silica gel (gradient 6% to 25% EtOAc in hexane): orange oil; IR (neat cm^{-1}): 3416 (NH), 2227 (C≡N); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.82 (t, *J* = 6.9 Hz, 2H), 2.87 (d, *J* = 5.2 Hz, 3H), 3.81 (t, *J* = 6.9 Hz, 2H), 4.47 (s, 2H), 4.66-4.71 (br m, 1H), 6.56 (d, *J* = 8.0 Hz, 1H), 6.60 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.19 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.24 (d, *J* = 8.0 Hz, 1H), 7.52 (d, *J* = 8.6 Hz, 2H), 7.59 (d, *J* = 8.6 Hz, 2H); $^{13}C\{^1H\}$

NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.3, 58.8, 68.6, 78.5, 84.8, 89.4, 92.0, 107.6, 108.9, 111.9, 116.0, 118.3, 127.4, 129.5, 131.8, 132.0 (2C), 132.2 (2C), 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{21}H_{18}N_2ONa$ 337.1311; found 337.1314.

***N*-Methyl-2-(4-{[3-(*p*-tolyl)prop-2-yn-1-yl]oxy}but-1-yn-1-yl)aniline (1n).** According to the procedure described for the preparation of **1a**, **S10** (106 mg, 0.497 mmol) was converted into **1n** (120 mg, 80%) by the reaction with 1-iodo-4-methylbenzene (119 mg, 0.546 mmol), $PdCl_2(PPh_3)_2$ (17.4 mg, 0.0248 mmol), CuI (4.73 mg, 0.0248 mmol) and Et_3N (0.22 mL) in DMF (1.7 mL) at room temperature for 9 h. Column chromatography: silica gel (gradient 1% to 5% EtOAc in hexane): yellow oil; IR (neat cm^{-1}): 3412 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.35 (s, 3H), 2.81 (t, *J* = 6.9 Hz, 2H), 2.87 (s, 3H), 3.81 (t, *J* = 6.9 Hz, 2H), 4.45 (s, 2H), 4.70-4.74 (br m, 1H), 6.55 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.11 (d, *J* = 8.0 Hz, 2H), 7.18 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.24 (d, *J* = 8.0 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 21.5, 30.3, 59.0, 68.3, 78.4, 84.0, 86.6, 92.2, 107.7, 108.7, 115.9, 119.4, 129.0 (2C), 129.4, 131.6 (2C), 131.7, 138.6, 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{21}H_{21}NNaO$ 326.1515, found 326.1519.

2-(4-{[3-(4-Methoxyphenyl)prop-2-yn-1-yl]oxy}but-1-yn-1-yl)-*N*-methylaniline (1o). According to the procedure described for the preparation of **1a**, **S10** (125 mg, 0.587 mmol) was converted into **1o** (63.3 mg, 34%) by the reaction with 1-iodo-4-methoxybenzene (137 mg, 0.587 mmol), $PdCl_2(PPh_3)_2$ (20.6 mg, 0.0293 mmol), CuI (5.59 mg, 0.0293 mmol) and Et_3N (0.26 mL) in DMF (2.0 mL) at 60 °C for 3 h. Column chromatography: silica gel (gradient 4% to 20% EtOAc in hexane): orange oil; IR (neat cm^{-1}): 3411 (NH); ^1H NMR (500 MHz, $CDCl_3$) δ: 2.81 (t, *J* = 6.6 Hz, 2H), 2.87 (d, *J* = 4.0 Hz, 3H), 3.79-3.83 (m, 5H), 4.44 (s, 2H), 4.70-4.74 (br m, 1H), 6.55 (d, *J* = 7.4 Hz, 1H), 6.59 (dd, *J* = 7.4, 7.4 Hz, 1H), 6.83 (d, *J* = 8.6 Hz, 2H), 7.18 (dd, *J* = 7.4, 7.4 Hz,

1H), 7.24 (d, *J* = 7.4 Hz, 1H), 7.39 (d, *J* = 8.6 Hz, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.3, 55.3, 59.0, 68.2, 78.4, 83.4, 86.4, 92.2, 107.7, 108.7, 113.9 (2C), 114.5, 115.9, 129.4, 131.7, 133.2 (2C), 150.0, 160.0; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{21}H_{21}NNaO_2$ 342.1465; found 342.1474.

2-(4-{[3-(3-Chlorophenyl)prop-2-yn-1-yl]oxy}but-1-yn-1-yl)-*N*-methylaniline (1p). According to the procedure described for the preparation of **1a**, **S10** (186 mg, 0.873 mmol) was converted into **1p** (219 mg, 78%) by the reaction with 1-chloro-3-iodobenzene (208 mg, 0.873 mmol), $PdCl_2(PPh_3)_2$ (30.6 mg, 0.0436 mmol), CuI (8.31 mg, 0.0436 mmol) and Et_3N (0.38 mL) in DMF (2.9 mL) at room temperature for 4 h. Column chromatography: silica gel (gradient 4% to 15% EtOAc in hexane): yellow oil; IR (neat cm^{-1}): 3425 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.80 (t, *J* = 6.9 Hz, 2H), 2.86 (d, *J* = 2.9 Hz, 3H), 3.79 (t, *J* = 6.9 Hz, 2H), 4.43 (s, 2H), 4.68-4.73 (br m, 1H), 6.54 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.16-7.20 (m, 1H), 7.20-7.23 (m, 1H), 7.23-7.26 (m, 1H), 7.27-7.33 (m, 2H), 7.43 (s, 1H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 20.9, 30.2, 58.8, 68.4, 78.4, 84.9, 86.1, 92.1, 107.6, 108.7, 115.9, 124.1, 128.7, 129.4, 129.5, 129.8, 131.5, 131.7, 134.0, 149.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}ClNO$ 324.1150; found 324.1153.

2-(4-{[3-(2-Chlorophenyl)prop-2-yn-1-yl]oxy}but-1-yn-1-yl)-*N*-methylaniline (1q). According to the procedure described for the preparation of **1a**, **S10** (187 mg, 0.879 mmol) was converted into **1q** (186 mg, 65%) by the reaction with 1-chloro-2-iodobenzene (210 mg, 0.879 mmol), $PdCl_2(PPh_3)_2$ (30.8 mg, 0.0439 mmol), CuI (8.37 mg, 0.0439 mmol) and Et_3N (0.38 mL) in DMF (2.9 mL) at room temperature for 4 h. Column chromatography: silica gel (gradient 4% to 15% EtOAc in hexane): yellow oil; IR (neat cm^{-1}): 3410 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.83 (t, *J* = 6.9 Hz, 2H), 2.87 (d, *J* = 5.2 Hz, 3H), 3.86 (t, *J* = 6.9 Hz, 2H), 4.52 (s, 2H), 4.68-4.74

(br m, 1H), 6.55 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.16-7.22 (m, 2H), 7.23-7.28 (m, 2H), 7.38-7.41 (m, 1H), 7.46-7.50 (m, 1H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.3, 58.9, 68.3, 78.4, 83.2, 90.1, 92.2, 107.7, 108.7, 115.9, 122.4, 126.4, 129.2, 129.4, 129.5, 131.7, 133.5, 135.9, 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{20}H_{18}ClNNaO$ 346.0969; found 346.0971.

***N*-Methyl-2-(4-{[3-(naphthalen-2-yl)prop-2-yn-1-yl]oxy}but-1-yn-1-yl)aniline (1r).** According to the procedure described for the preparation of **1a**, **S10** (125 mg, 0.588 mmol) was converted into **1r** (80.6 mg, 40%) by the reaction with 2-bromonaphthalene (134 mg, 0.647 mmol), $PdCl_2(PPh_3)_2$ (20.6 mg, 0.0294 mmol), CuI (5.60 mg, 0.0294 mmol) and Et_3N (0.26 mL) in DMF (2.0 mL) at room temperature for 1.5 h and 60 °C for 4.5 h. Column chromatography: silica gel (gradient 4% to 15% EtOAc in hexane): yellow oil; IR (neat cm^{-1}): 3416 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.83 (t, *J* = 6.9 Hz, 2H), 2.86 (d, *J* = 4.0 Hz, 3H), 3.85 (t, *J* = 6.9 Hz, 2H), 4.50 (s, 2H), 4.71-4.76 (br m, 1H), 6.54 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.18 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.26 (d, *J* = 8.0 Hz, 1H), 7.46-7.50 (m, 3H), 7.73-7.81 (m, 3H), 7.97 (s, 1H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 30.2, 59.0, 68.4, 78.4, 85.1, 86.8, 92.2, 107.7, 108.7, 115.9, 119.7, 126.5, 126.7, 127.7 (2C), 128.0, 128.3, 129.4, 131.7 (2C), 132.8 (2C), 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{24}H_{22}NO$ 340.1696; found 340.1698.

2-[4-(But-2-yn-1-yloxy)but-1-yn-1-yl]-*N*-methylaniline (1s). According to the procedure described for the preparation of **1a**, **S2a** (427 mg, 1.83 mmol) was converted into **1s** (179 mg, 43%) by the reaction with 4-(but-2-yn-1-yloxy)but-1-yne (**S5g**) (246 mg, 2.01 mmol), $PdCl_2(PPh_3)_2$ (64.3 mg, 0.0915 mmol), CuI (17.4 mg, 0.0915 mmol) and Et_3N (0.80 mL) in DMF (6.1 mL) at room temperature for 24 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3406 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.87 (t, *J* = 2.3 Hz,

3H), 2.77 (t, *J* = 6.9 Hz, 2H), 2.90 (d, *J* = 5.2 Hz, 3H), 3.72 (t, *J* = 6.9 Hz, 2H), 4.18 (q, *J* = 2.3 Hz, 2H), 4.68-4.73 (br m, 1H), 6.56 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.19 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.24 (d, *J* = 8.0 Hz, 1H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 3.58, 20.9, 30.2, 58.7, 68.1, 74.8, 78.3, 82.7, 92.2, 107.7, 108.7, 115.8, 129.3, 131.7, 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{15}H_{18}NO$ 228.1383; found 228.1388.

2-{4-[(3-Phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1t). According to the procedure described for the preparation of **1a**, 2-iodoaniline (424 mg, 1.93 mmol) was converted into **1t** (196 mg, 37%) by the reaction with **S5a** (384 mg, 2.13 mmol), $PdCl_2(PPh_3)_2$ (67.9 mg, 0.0967 mmol), CuI (18.4 mg, 0.0967 mmol) and Et_3N (0.85 mL) in DMF (6.5 mL) at room temperature for 6 h. Column chromatography: silica gel (hexane/acetone = 10/1): orange oil; IR (neat cm^{-1}): 3472 (NH), 3478 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.81 (t, *J* = 6.9 Hz, 2H), 3.82 (t, *J* = 6.9 Hz, 2H), 4.21 (s, 2H), 4.45 (s, 2H), 6.63-6.67 (m, 2H), 7.08 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.24 (d, *J* = 7.7 Hz, 1H), 7.28-7.34 (m, 3H), 7.43-7.47 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 20.9, 58.9, 68.3, 78.3, 84.8, 86.4, 91.9, 108.3, 114.1, 117.7, 122.5, 128.3 (2C), 128.5, 129.1, 131.8 (2C), 131.9, 147.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{19}H_{18}NO$ 276.1383; found 276.1373.

***N*-Benzyl-2-{4-[(3-phenylprop-2-yn-1-yl)oxy]but-1-yn-1-yl}aniline (1u).** According to the procedure described for the preparation of **1a**, *N*-benzyl-2-iodoaniline (**S2k**) (198 mg, 0.641 mmol) was converted into **1u** (176 mg, 75%) by the reaction with **S5a** (127 mg, 0.705 mmol), $PdCl_2(PPh_3)_2$ (22.5 mg, 0.0320 mmol), CuI (6.10 mg, 0.0320 mmol) and Et_3N (0.28 mL) in DMF (2.1 mL) at room temperature for 7 h. Column chromatography: silica gel (gradient 1% to 10% EtOAc in hexane): yellow oil; IR (neat cm^{-1}): 3405 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.80 (t, *J* = 6.9 Hz, 2H), 3.78 (t, *J* = 6.9 Hz, 2H), 4.34 (s, 2H), 4.41 (d, *J* = 5.7 Hz, 2H), 5.15-5.19 (br m, 1H), 6.51 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.10 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.22-

7.38 (m, 9H), 7.41 (dd, J = 7.7, 1.4 Hz, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.0, 47.6, 58.9, 68.2, 78.4, 84.8, 86.4, 92.5, 107.9, 109.7, 116.3, 122.4, 127.1 (3C), 128.3 (2C), 128.5, 128.6 (2C), 129.3, 131.7 (2C), 131.8, 139.3, 148.9; HRMS (ESI-TOF) m/z: $[M + H]^+$ calcd for $C_{26}H_{24}NO$ 366.1852; found 366.1854.

***N*-Methyl-2-{3-[(3-phenylprop-2-yn-1-yl)oxy]prop-1-yn-1-yl}aniline (1v).** According to the procedure described for the preparation of **1a**, **S2a** (190 mg, 0.817 mmol) was converted into **1v** (136 mg, 61%) by the reaction with [3-(prop-2-yn-1-yloxy)prop-1-yn-1-yl]benzene (**S5b**) (153 mg, 0.899 mmol), $PdCl_2(PPh_3)_2$ (28.7 mg, 0.0408 mmol), CuI (7.78 mg, 0.0408 mmol) and Et_3N (0.36 mL) in DMF (2.7 mL) at room temperature for 6 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3419 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.88 (d, J = 5.2 Hz, 3H), 4.55 (s, 2H), 4.61 (s, 2H), 4.63-4.66 (br m, 1H), 6.58 (d, J = 8.0 Hz, 1H), 6.62 (dd, J = 8.0, 8.0 Hz, 1H), 7.24 (dd, J = 8.0, 8.0 Hz, 1H), 7.29-7.35 (m, 4H), 7.44-7.48 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 30.2, 57.3, 57.6, 83.7, 84.3, 86.8, 89.9, 106.3, 108.9, 116.0, 122.4, 128.3 (2C), 128.6, 130.3, 131.8 (2C), 132.5, 150.1; HRMS (ESI-TOF) m/z: $[M + H]^+$ calcd for $C_{19}H_{18}NO$ 276.1383; found 276.1375.

***N*-Methyl-2-{5-[(3-phenylprop-2-yn-1-yl)oxy]pent-1-yn-1-yl}aniline (1w).** According to the procedure described for the preparation of **1a**, **S2a** (148 mg, 0.634 mmol) was converted into **1w** (104 mg, 54%) by the reaction with **S5c** (138 mg, 0.698 mmol), $PdCl_2(PPh_3)_2$ (22.3 mg, 0.0317 mmol), CuI (6.04 mg, 0.0317 mmol) and Et_3N (0.28 mL) in DMF (2.1 mL) at room temperature for 19 h. Column chromatography: silica gel (hexane/acetone = 20/1): yellow oil; IR (neat cm^{-1}): 3422 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.95 (tt, J = 6.9, 6.9 Hz, 2H), 2.62 (t, J = 6.9 Hz, 2H), 2.86 (d, J = 4.6 Hz, 3H), 3.75 (t, J = 6.9 Hz, 2H), 4.40 (s, 2H), 4.58-5.64 (br m, 1H), 6.55 (d, J = 8.0 Hz, 1H), 6.58 (dd, J = 8.0, 8.0 Hz, 1H), 7.18 (dd, J = 8.0, 8.0 Hz, 1H), 7.23 (d, J = 8.0 Hz, 1H),

7.26-7.33 (m, 3H), 7.41-7.45 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 16.6, 28.9, 30.3, 58.9, 68.7, 77.4, 85.1, 86.2, 95.0, 108.1, 108.7, 116.0, 122.5, 128.2 (2C), 128.4, 129.2, 131.7 (2C), 131.9, 149.7; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1697.

4-Methyl-*N*-{4-[2-(methylamino)phenyl]but-3-yn-1-yl}-*N*-(3-phenylprop-2-yn-1-yl)benzenesulfonamide (1x). According to the procedure described for the preparation of **1a**, **S2a** (144 mg, 0.619 mmol) was converted into **1x** (111 mg, 41%) by the reaction with **S5d** (230 mg, 0.681 mmol), $PdCl_2(PPh_3)_2$ (16.7 mg, 0.0237 mmol), CuI (4.52 mg, 0.0237 mmol) and Et_3N (0.21 mL) in DMF (1.6 mL) at room temperature for 5.5 h. Column chromatography: silica gel (gradient 2% to 5% EtOAc in hexane): yellow oil; IR (neat cm^{-1}): 3408 (NH), 1346 (S=O), 1161 (S=O); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.34 (s, 3H), 2.84 (t, *J* = 6.9 Hz, 2H), 2.89 (s, 3H), 3.53 (t, *J* = 6.9 Hz, 2H), 4.45 (s, 2H), 4.82-4.87 (br m, 1H), 6.54-6.60 (m, 2H), 7.07 (d, *J* = 8.0 Hz, 2H), 7.19 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.21-7.30 (m, 6H), 7.80 (d, *J* = 8.0 Hz, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 19.9, 21.4, 30.1, 37.7, 45.6, 79.3, 81.6, 85.8, 91.5, 107.3, 108.8, 115.7, 122.0, 127.7 (2C), 128.1 (2C), 128.5, 129.6 (3C), 131.5 (2C), 131.8, 135.8, 143.6, 150.1; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{27}H_{27}N_2O_2S$ 443.1788; found 443.1778.

(*S*)-2-{4-[(4-Phenylbut-3-yn-2-yl)oxy]but-1-yn-1-yl}aniline (S11). According to the procedure described for the preparation of **1a**, 2-iodoaniline (253 mg, 1.16 mmol) was converted into **S11** (163 mg, 49%) by the reaction with **S5e** (252 mg, 1.27 mmol), $PdCl_2(PPh_3)_2$ (40.6 mg, 0.0578 mmol), CuI (11.0 mg, 0.0578 mmol) and Et_3N (0.50 mL) in DMF (3.9 mL) at room temperature for 9 h. Column chromatography: silica gel (gradient 4% to 10% EtOAc in hexane): yellow oil; $[\alpha]^{25}_D$ –120.3 (*c* 0.67, $CHCl_3$); IR (neat cm^{-1}): 3364 (NH), 3474 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.55 (d, *J* = 6.3 Hz, 3H), 2.80 (t, *J* = 6.9 Hz, 2H), 3.71 (dt, *J* = 9.2, 6.9 Hz, 1H), 3.99 (dt, *J* = 9.2, 6.9 Hz, 1H), 4.21 (s, 2H), 4.48 (q, *J* = 6.3 Hz, 1H), 6.62-6.68 (m, 2H), 7.07 (dd, *J* = 7.4, 7.4 Hz,

1H), 7.23 (d, *J* = 7.4 Hz, 1H), 7.27-7.32 (m, 3H), 7.42-7.46 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.1, 22.2, 65.9, 67.1, 78.2, 85.1, 88.8, 92.2, 108.4, 114.0, 117.7, 122.6, 128.2 (2C), 128.3, 129.0, 131.7 (2C), 131.8, 147.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{20}NO$ 290.1539; found 290.1539.

(*S*)-*N*-Methyl-2-{4-[(4-phenylbut-3-yn-2-yl)oxy]but-1-yn-1-yl}aniline (1y). To a stirred solution of **S11** (156 mg, 0.539 mmol) in THF (0.90 mL) was added MeLi (1.1 M in Et_2O; 0.79 mL, 0.863 mmol) at –78 °C under argon. After the mixture was stirred for 1 h at this temperature, MeI (50.4 μL, 0.809 mmol) was added to the mixture. The mixture was gradually warmed to room temperature and stirred for 5 h at this temperature. The reaction was quenched with saturated aqueous NH_4Cl. The resulting mixture was extracted with EtOAc twice. The combined organic layer was washed with brine, dried over Na_2SO_4, filtered, and concentrated in vacuo. The residue was purified by column chromatography on silica gel (gradient 2% to 5% EtOAc in hexane) to give **1y** (39.5 mg, 24%) as a colorless oil; $[\alpha]^{25}_D$ –105.6 (*c* 0.59, $CHCl_3$); IR (neat cm^{-1}): 3400 (NH); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.56 (d, *J* = 6.3 Hz, 3H), 2.80 (t, *J* = 6.9 Hz, 2H), 2.87 (s, 3H), 3.71 (dt, *J* = 9.2, 6.9 Hz, 1H), 3.99 (dt, *J* = 9.2, 6.9 Hz, 1H), 4.49 (q, *J* = 6.3 Hz, 1H), 4.70-4.74 (br m, 1H), 6.55 (d, *J* = 8.0 Hz, 1H), 6.59 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.18 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.24 (d, *J* = 8.0 Hz, 1H), 7.27-7.32 (m, 3H), 7.41-7.46 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 21.1, 22.2, 30.2, 65.9, 67.1, 78.2, 85.1, 88.8, 92.5, 107.8, 108.7, 115.9, 122.6, 128.3 (2C), 128.4, 129.4, 131.7 (3C), 150.0; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1695.

3. Gold-Catalyzed Cascade Cyclization

(*Z*)-11-Methyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2a) and 4-Methyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3a). Condition A: To a stirred mixture of **1a** (303 mg, 1.05 mmol) in EtOH (10 mL) was added 5 mol % IPrAuNTf$_2$ (45.3 mg, 0.0523 mmol) at room temperature. After being stirred for 10 min at 60 ℃, the reaction mixture was filtered through a short pad of celite and silica gel, and the filtrate was evaporated in vacuo to give a crude product, which was purified by column chromatography on amine silica gel (hexane/EtOAc = 25/1 to 0/100) to give **2a** (258 mg, 85%) and **3a** (22.5 mg, 7%). **Condition B**: To a stirred mixture of **1a** (309 mg, 1.07 mmol) in *i*-PrOH (11 mL) was added 5 mol % JohnPhosAuNTf$_2$ (41.4 mg, 0.0533 mmol) at room temperature. After being stirred for 5 min at 80 ℃, the reaction mixture was filtered through a short pad of celite and silica gel, and the filtrate was evaporated in vacuo to give a crude product, which was purified by column chromatography on amine silica gel (hexane/EtOAc = 30/1 to 10/1) to give **2a** (24.7 mg, 8%) and **3a** (251 mg, 81%). Compound **2a**: pale yellow solid; mp 183-186 ℃; ^{1}H NMR (500 MHz, CDCl$_3$) δ: 2.83-2.94 (br m, 1H), 3.22-3.35 (br m, 2H), 3.46-3.56 (br m, 1H), 3.79 (s, 3H), 4.12-4.18 (br m, 1H), 4.44-4.51 (br m, 1H), 6.28 (dd, *J* = 8.3, 8.3 Hz, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 6.89 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.16 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.28-7.34 (m, 4H), 7.39-7.44 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, CDCl$_3$) δ: 28.4, 29.8, 63.3, 67.8, 109.0, 111.3, 119.5, 120.3, 121.3, 122.4, 126.6, 127.8, 128.0 (2C), 128.2 (2C), 137.1, 138.8, 140.9, 141.0; HRMS (ESI-TOF) *m*/*z*: [M + H]$^+$ calcd for C$_{20}$H$_{20}$NO 290.1539; found 290.1539. Compound **3a**: ^{1}H NMR (500 MHz, CDCl$_3$) δ: 2.02-2.07 (m, 1H), 2.31-2.36 (m, 1H), 2.67 (dd, *J* = 17.8, 2.6 Hz, 1H), 2.72 (dd, *J* = 17.8, 2.6 Hz, 1H), 2.86 (s, 3H), 3.81-3.86 (m, 1H), 4.02-4.06 (m, 1H), 6.09 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.36 (d, *J* = 7.4 Hz, 1H), 6.46 (dd, *J* = 7.4, 7.4 Hz, 1H), 7.08-7.12 (m, 2H), 7.28-7.31 (m, 1H), 7.34-7.37 (m, 2H), 7.83-7.84 (m, 2H). The ^{1}H NMR spectra were in good agreement with those reported.[9]

(*Z*)-8-Fluoro-11-methyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2b) and 7-Fluoro-4-methyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3b). According to the procedure described for **Condition A**, **1b** (56.1 mg, 0.192 mmol) was converted into **2b** (40.1 mg, 68%) and **3b** (1.6 mg, 3%) by the reaction with $IPrAuNTf_2$ (8.34 mg, 0.00962 mmol) in EtOH (1.9 mL) at 60 ℃ for 40 min. Column chromatography: amine silica gel (gradient 2% to 5% EtOAc in hexane). According to the procedure described for **Condition B**, **1b** (66.1 mg, 0.215 mmol) was converted into **2b** (14.8 mg, 22%) and **3b** (44.0 mg, 67%) by the reaction with $IPrAuNTf_2$ (8.34 mg, 0.0108 mmol) in *i*-PrOH (2.2 mL) at 80 ℃ for 10 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). Compound **2b**: pale yellow solid; mp 167-170 ℃; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.83-2.93 (br m, 1H), 3.18-3.34 (br m, 2H), 3.45-3.54 (br m, 1H), 3.77 (s, 3H), 4.10-4.19 (br m, 1H), 4.43-4.52 (br m, 1H), 6.25 (dd, J = 8.0, 8.0 Hz, 1H), 6.43 (dd, J = 9.0, 2.3 Hz, 1H), 6.88 (ddd, J = 9.0, 9.0, 2.3 Hz, 1H), 7.21 (dd, J = 9.0, 4.3 Hz, 1H), 7.28-7.33 (m, 3H), 7.36-7.40 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 28.6, 30.0, 63.4, 67.8, 105.3 (d, $J_{C\text{-}F}$ = 22.8 Hz), 109.5 (2C), 111.4 (d, $J_{C\text{-}F}$ = 4.8 Hz), 122.7, 126.9 (d, $J_{C\text{-}F}$ = 10.8 Hz), 127.9 (2C), 128.0, 128.3 (2C), 133.6, 140.3, 140.5, 140.6, 157.9 (d, $J_{C\text{-}F}$ = 235.1 Hz); HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}FNO$ 308.1445; found 308.1436. Compound **3b**: yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.00-2.07 (m, 1H), 2.29-2.35 (m, 1H), 2.67 (dd, J = 17.5, 2.6 Hz, 1H), 2.73 (dd, J = 17.5, 2.6 Hz, 1H), 2.84 (s, 3H), 3.83-3.89 (m, 1H), 4.02-4.07 (m, 1H), 6.12 (dd, J = 2.9, 2.9 Hz, 1H), 6.23-6.27 (m, 1H), 6.78-6.83 (m, 2H), 7.29-7.33 (m, 1H), 7.35-7.39 (m, 2H), 7.78-7.81 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 30.3, 38.6, 40.6, 68.0, 85.6, 103.8, 105.8 (d, $J_{C\text{-}F}$ = 8.4 Hz), 112.2 (d, $J_{C\text{-}F}$ = 24.0 Hz), 115.8 (d, $J_{C\text{-}F}$ = 22.8 Hz), 127.1 (2C), 127.9, 128.2 (d, $J_{C\text{-}F}$ = 9.6 Hz), 128.4 (2C), 129.3, 134.4, 142.6, 148.3, 155.6 (d,

$J_{C\text{-}F}$ = 230.3 Hz); HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{20}H_{18}FNNaO$ 330.1265; found 330.1259.

(*Z*)-8-Chloro-11-methyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2c) and 7-Chloro-4-methyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3c). According to the procedure described for **Condition A**, **1c** (53.2 mg, 0.164 mmol) was converted into **2c** (34.2 mg, 64%) and **3c** (trace) by the reaction with $IPrAuNTf_2$ (7.12 mg, 0.00821 mmol) in EtOH (1.6 mL) at 60 °C for 25 min. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). According to the procedure described for **Condition B**, **1c** (49.8 mg, 0.154 mmol) was converted into **2c** (6.6 mg, 13%) and **3c** (39.5 mg, 79%) by the reaction with $JohnPhosAuNTf_2$ (5.96 mg, 0.00769 mmol) in *i*-PrOH (1.5 mL) at 80 °C for 20 min. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). Compound **2c**: white solid; mp 176-179 °C; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.81-2.93 (br m, 1H), 3.18-3.32 (br m, 2H), 3.40-3.52 (br m, 1H), 3.76 (s, 3H), 4.09-4.18 (br m, 1H), 4.45-4.47 (br m, 1H), 6.27 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.75 (d, *J* = 2.0 Hz, 1H), 7.09 (dd, *J* = 8.9, 2.0 Hz, 1H), 7.21 (d, *J* = 8.9 Hz, 1H), 7.29-7.33 (m, 3H), 7.35-7.40 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.5, 29.9, 63.4, 67.8, 110.1, 111.0, 119.6, 121.5, 123.0, 125.1, 127.5, 127.8 (2C), 128.0, 128.3 (2C), 135.5, 140.0, 140.2, 140.5; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}ClNO$ 324.1150; found 324.1142. Compound **3c**: yellow oil; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.99-2.06 (m, 1H), 2.28-2.34 (m, 1H), 2.64-2.74 (m, 2H), 2.83 (s, 3H), 3.78-3.85 (m, 1H), 4.00-4.05 (m, 1H), 6.11 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.26 (d, *J* = 8.6 Hz, 1H), 7.00-7.06 (m, 2H), 7.29-7.33 (m, 1H), 7.35-7.39 (m, 2H), 7.78-7.82 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 29.8, 38.6, 40.8, 67.9, 85.5, 103.9, 106.5, 121.1, 124.9, 127.4 (2C), 127.9, 128.4 (2C), 128.8, 129.2, 129.5, 134.3, 142.5, 150.4; HRMS (ESI-TOF) *m*/*z*: $[M + Na]^+$ calcd for $C_{20}H_{18}ClNNaO$ 346.0969; found 346.0966.

(*Z*)-8-Bromo-11-methyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2d) and 7-Bromo-4-methyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3d). According to the procedure described for **Condition A**, **1d** (69.3mg, 0.188mmol) was converted into **2d** (42.9 mg, 62%) and **3d** (4.1mg, 6%) by the reaction with $IPrAuNTf_2$ (8.16mg, 0.00941mmol) in EtOH (1.9 mL) at 60 ℃ for 20 min. Column chromatography: amine silica gel (hexane/EtOAc = 25/1 to 15/1). According to the procedure described for **Condition B**, **1d** (60.5 mg, 0.164 mmol) was converted into **2d** (6.9 mg, 11%) and **3d** (49.9 mg, 82%) by the reaction with $JohnPhosAuNTf_2$ (6.37 mg, 0.00822 mmol) in *i*-PrOH (1.6 mL) at 80 ℃ for 10 min. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). Compound **2d**: yellow solid; mp 133-138 ℃; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.82-2.92 (br m, 1H), 3.19-3.32 (br m, 2H), 3.41-3.51 (br m, 1H), 3.76-3.78 (br m, 3H), 4.09-4.19 (br m, 1H), 4.42-4.51 (br m, 1H), 6.28 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.91 (d, *J* = 1.7 Hz, 1H), 7.18 (d, *J* = 9.0 Hz, 1H), 7.23 (dd, *J* = 9.0, 1.7 Hz, 1H), 7.29-7.34 (m, 3H), 7.36-7.40 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 28.4, 29.9, 63.4, 67.8, 110.5, 111.0, 112.8, 122.6, 123.1, 124.2, 127.8 (2C), 128.0, 128.2, 128.3 (2C), 135.8, 139.9, 140.1, 140.4; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0647. Compound **3d**: yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.99-2.07 (m, 1H), 2.28-2.35 (m, 1H), 2.65-2.75 (m, 2H), 2.84 (s, 3H), 3.78-3.85 (m, 1H), 4.00-4.06 (m, 1H), 6.11 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.23 (d, *J* = 8.6 Hz, 1H), 7.14 (d, *J* = 1.7 Hz, 1H), 7.18 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.29-7.34 (m, 1H), 7.35-7.40 (m, 2H), 7.78-7.82 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 29.8, 38.6, 40.8, 67.9, 85.4, 103.9, 107.1, 108.1, 127.1 (2C), 127.7, 127.9, 128.4 (2C), 129.1, 129.3, 132.4, 134.2, 142.6, 150.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0643.

(*Z*)-8,11-Dimethyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2e) and 4,7-Dimethyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3e). According to the

procedure described for **Condition A**, **1e** (41.5 mg, 0.137 mmol) was converted into **2e** (31.8 mg, 77%) and **3e** (1.2 mg, 3%) by the reaction with IPrAuNTf$_2$ (6.07 mg, 0.00684 mmol) in EtOH (1.4 mL) at 60 °C for 20 min. Column chromatography: amine silica gel (gradient 0% to 10% EtOAc in hexane). According to the procedure described for **Condition B**, **1e** (51.4 mg, 0.169 mmol) was converted into **2e** (3.0 mg, 6%) and **3e** (39.5 mg, 77%) by the reaction with JohnPhosAuNTf$_2$ (6.57 mg, 0.00847 mmol) in *i*-PrOH (1.7 mL) at 80 °C for 2 h. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). Compound **2e**: white solid; mp 173-175 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.24 (s, 3H), 2.80-2.89 (br m, 1H), 3.20-3.30 (br m, 2H), 3.43-3.51 (br m, 1H), 3.76 (s, 3H), 4.08-4.16 (br m, 1H), 4.42-4.49 (br m, 1H), 6.28 (dd, *J* = 8.3, 8.3 Hz, 1H), 6.60 (s, 1H), 6.98 (d, *J* = 8.6 Hz, 1H), 7.21 (d, *J* = 8.6 Hz, 1H), 7.28-7.32 (m, 3H), 7.40-7.44 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 21.4, 28.5, 29.8, 63.4, 67.9, 108.8, 110.7, 119.9, 122.4, 122.8, 126.8, 127.7, 127.9 (2C), 128.2 (2C), 128.8, 135.5, 138.9, 140.9 (2C); HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{21}H_{21}NNaO$ 326.1515; found 326.1508. Compound **3e**: yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.97-2.05 (m, 1H), 2.08 (s, 3H), 2.29-2.35 (m, 1H), 2.61-2.74 (m, 2H), 2.83 (s, 3H), 3.82-3.88 (m, 1H), 4.00-4.05 (m, 1H), 6.10 (dd, *J* = 2.3, 2.3 Hz, 1H), 6.30 (d, *J* = 8.6 Hz, 1H), 6.89-6.94 (m, 2H), 7.27-7.32 (m, 1H), 7.34-7.39 (m, 2H), 7.82-7.86 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 20.7, 30.1, 38.5, 40.4, 67.9, 85.3, 104.3, 105.9, 125.4, 126.2, 127.3 (2C), 127.4, 127.6, 128.2 (2C), 128.8, 130.2, 134.7, 143.0, 149.9; HRMS (ESI-TOF) *m*/*z*: [M + Na]$^+$ calcd for $C_{21}H_{21}NNaO$ 326.1515; found 326.1511.

(*Z*)-8-Methoxy-11-methyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2f) and 7-Methoxy-4-methyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3f). According to the procedure described for **Condition A**, **1f** (50.2 mg, 0.157 mmol) was converted into **2f** (37.4 mg, 75%) and **3f** (2.6mg, 5%) by the reaction with IPrAuNTf$_2$ (6.81 mg, 0.00786 mmol) in EtOH

(1.6 mL) at 60 °C for 15 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane) and PTLC (hexane/EtOAc = 3/1). According to the procedure described for **Condition B**, **1f** (42.9 mg, 0.134 mmol) was converted into **2f** (6.9 mg, 16%) and **3f** (27.9 mg, 65%) by the reaction with JohnPhosAuNTf$_2$ (5.21 mg, 0.00672 mmol) in *i*-PrOH (1.3 mL) at 80 °C for 1 h. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). Compound **2f**: white solid; mp 156-158 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.81-2.92 (br m, 1H), 3.17-3.36 (br m, 2H), 3.49-3.59 (br m, 4H), 3.75 (s, 3H), 4.09-4.20 (br m, 1H), 4.43-4.53 (br m, 1H), 6.22 (d, *J* = 2.3 Hz, 1H), 6.25 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.80 (dd, *J* = 8.6, 2.3 Hz, 1H), 7.19 (d, *J* = 8.6 Hz, 1H), 7.27-7.32 (m, 3H), 7.40-7.44 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 28.6, 29.9, 55.6, 63.4, 67.9, 102.5, 109.6, 111.0 (2C), 122.1, 126.9, 127.8, 128.0 (2C), 128.2 (2C), 132.3, 139.3, 140.8, 141.0, 153.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO_2$ 320.1645; found 320.1645. Compound **3f**: brown solid; mp 91-93 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.98-2.05 (m, 1H), 2.28-2.34 (m, 1H), 2.64 (dd, *J* = 17.5, 2.6 Hz, 1H), 2.72 (dd, *J* = 17.5, 2.6 Hz, 1H), 2.82 (s, 3H), 3.56 (s, 3H), 3.85-3.90 (m, 1H), 4.01-4.07 (m, 1H), 6.11 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.31 (d, *J* = 8.0 Hz, 1H), 6.70 (dd, *J* = 8.0, 2.9 Hz, 1H), 6.74 (d, *J* = 2.9 Hz, 1H), 7.25-7.30 (m, 1H), 7.32-7.37 (m, 2H), 7.79-7.83 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 30.5, 38.4, 40.3, 55.9, 68.1, 85.5, 104.1, 106.4, 111.8, 115.1, 127.3 (2C), 127.7, 128.3 (3C), 129.1, 134.7, 142.9, 146.6, 152.0; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO_2$ 320.1645; found 320.1635.

(*Z*)-11-Methyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole-8-carbonitrile (2g). According to the procedure described for **Condition A**, **1g** (46.2 mg, 0.147 mmol) was converted into **2g** (8.0 mg, 17%) by the reaction with IPrAuNTf$_2$ (6.37 mg, 0.00735 mmol) in EtOH (1.5 mL) at 60 °C for 6.5 h, and additional 11.5 h after addition of a second portion of IPrAuNTf$_2$ (6.37

mg, 0.00735 mmol). Column chromatography: amine silica gel (gradient 6% to 50% EtOAc in hexane) and PTLC (toluene/EtOAc = 5/1). According to the procedure described for **Condition B**, **1g** (48.6 mg, 0.155 mmol) was converted into **2g** (2.4 mg, 5%) by the reaction with JohnPhosAuNTf$_2$ (5.99 mg, 0.00773 mmol) in *i*-PrOH (1.5 mL) at 80 ℃ for 6 h. Column chromatography: amine silica gel (gradient 6% to 20% EtOAc in hexane) and PTLC (toluene/EtOAc = 5/1). Compound **2g**: yellow solid; mp 230-234 ℃; IR (neat cm^{-1}): 2220 (C≡N) ^{1}H NMR (500 MHz, CDCl$_3$) δ: 2.86-2.98 (br m, 1H), 3.21-3.38 (br m, 2H), 3.43-3.55 (br m, 1H), 3.83 (s, 3H), 4.13-4.20 (br m, 1H), 4.44-4.53 (br m, 1H), 6.30 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.12 (s, 1H), 7.31-7.41 (m, 7H); ^{13}C{^{1}H} NMR (125 MHz, CDCl$_3$) δ: 28.4, 30.1, 63.2, 67.8, 102.5, 109.9, 112.4, 120.7, 123.8, 124.5, 125.6, 126.4, 127.7 (2C), 128.3, 128.5 (2C), 138.7, 139.5, 140.3, 140.8; HRMS (ESI-TOF) *m*/*z*: [M + H]$^+$ calcd for $C_{21}H_{19}N_2O$ 315.1492; found 315.1494.

8-Bromo-4-methyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3h). The reaction of **1h** (28.3 mg, 0.768 mmol) with IPrAuNTf$_2$ (3.33 mg, 0.00384 mmol) in EtOH (0.77 mL) under **condition A** gave a mixture of unidentified products without producing **2h**/**3h**. According to the procedure described for **Condition B**, **1h** (26.6 mg, 0.0722 mmol) was converted into **3h** (10.9 mg, 44%) by the reaction with JohnPhosAuNTf$_2$ (2.80 mg, 0.00361 mmol) in *i*-PrOH (0.72 mL) at 80 ℃ for 5 h. PTLC (hexane/acetone = 5/1). Compound **3h**: yellow solid; mp 174-176 ℃; ^{1}H NMR (500 MHz, CDCl$_3$) δ: 2.08-2.14 (m, 1H), 2.22-2.28 (m, 1H), 2.63 (dd, *J* = 17.2, 2.3 Hz, 1H), 2.75 (dd, *J* = 17.2, 2.3 Hz, 1H), 2.87 (s, 3H), 3.93-3.99 (m, 1H), 4.07-4.13 (m, 1H), 5.81 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.31 (d, *J* = 8.0 Hz, 1H), 6.64 (d, *J* = 8.0 Hz, 1H), 6.93 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.26-7.30 (m, 3H), 7.43-7.46 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, CDCl$_3$) δ: 30.1, 38.0, 41.0, 68.0, 85.9, 104.9, 105.6, 119.8, 121.9, 126.3, 127.2, 127.6 (2C), 129.1 (2C), 130.8,

132.8, 138.1, 144.0, 153.4; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0646.

(*Z*)-9-Bromo-11-methyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2i) and 6-Bromo-4-methyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3i). According to the procedure described for **Condition A**, **1i** (60.6 mg, 0.165 mmol) was converted into **2i** (38.9 mg, 64%) and **3i** (11.7 mg, <19%) including inseparable impurities by the reaction with $IPrAuNTf_2$ (7.13 mg, 0.00823 mmol) in EtOH (1.7 mL) at 60 ℃ for 30 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). According to the procedure described for **Condition B**, **1i** (55.1 mg, 0.150 mmol) was converted into **2i** (3.4 mg, 6%) and **3i** (43.4 mg, 79%) by the reaction with $JohnPhosAuNTf_2$ (5.80 mg, 0.00748 mmol) in *i*-PrOH (1.5 mL) at 80 ℃ for 10 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). Compound **2i**: yellow solid; mp 169-172 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.82-2.91 (br m, 1H), 3.19-3.35 (br m, 2H), 3.45-3.54 (br m, 1H), 3.75 (s, 3H), 4.09-4.19 (br m, 1H), 4.42-4.52 (br m, 1H), 6.27 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.63 (d, *J* = 8.3 Hz, 1H), 6.97 (dd, *J* = 8.3, 1.7 Hz, 1H), 7.27-7.32 (m, 3H), 7.35-7.39 (m, 2H), 7.46 (d, *J* = 1.7 Hz, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.4, 29.9, 63.3, 67.8, 111.5, 112.1, 114.9, 121.5, 122.7, 122.9, 125.4, 127.9 (3C), 128.2 (2C), 137.9, 139.3, 140.3, 140.7; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0643. Compound **3i**: yellow solid; mp 108-111 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.00-2.07 (m, 1H), 2.29-2.34 (m, 1H), 2.65-2.74 (m, 2H), 2.84 (s, 3H), 3.78-3.83 (m, 1H), 4.00-4.06 (m, 1H), 6.08 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.47 (d, *J* = 1.7 Hz, 1H), 6.55 (dd, *J* = 8.0, 1.7 Hz, 1H), 6.89 (d, *J* = 8.0 Hz, 1H), 7.27-7.32 (m, 1H), 7.33-7.38 (m, 2H), 7.76-7.81 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 29.6, 38.8, 41.1, 67.7, 85.4, 103.9, 108.6, 119.4, 123.9, 125.9, 126.3, 127.3 (2C),

127.8, 128.3 (2C), 129.0, 134.4, 142.6, 152.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0642.

(*Z*)-10-Bromo-11-methyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2j) and 5-Bromo-4-methyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3j). According to the procedure described for **Condition A**, **1j** (27.3 mg, 0.0742 mmol) was converted into **2j** (19.3 mg, 71%) and **3j** (trace) by the reaction with $IPrAuNTf_2$ (3.22 mg, 0.00371 mmol) in EtOH (0.74 mL) at 60 ℃ for 30 min. Column chromatography: amine silica gel (hexane/EtOAc = 25/1) and amine PTLC (hexane/EtOAc = 10/1 × 2). According to the procedure described for **Condition B**, **1j** (25.1 mg, 0.0683 mmol) was converted into **2j** (2.4 mg, 9%) and **3j** (30.0 mg, 80%) by the reaction with $JohnPhosAuNTf_2$ (2.65 mg, 0.00341 mmol) in *i*-PrOH (0.68 mL) at 80 ℃ for 30 min. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). Compound **2j**: white solid; mp 206-208 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.83-2.90 (m, 1H), 3.23-3.33 (m, 2H), 3.44-3.50 (m, 1H), 4.11-4.16 (m, 1H), 4.19 (s, 3H), 4.43-4.49 (m, 1H), 6.30 (dd, *J* = 8.6, 6.9 Hz, 1H), 6.66-6.74 (m, 2H), 7.26-7.32 (m, 4H), 7.34-7.39 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.3, 32.6, 63.5, 67.8, 103.5, 112.0, 119.7, 120.6, 123.6, 126.9, 127.8 (2C), 127.9, 128.3 (2C), 129.6, 133.5, 140.0, 140.6, 140.7; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0648. Compound **3j**: colorless oil; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.03-2.10 (m, 1H), 2.37-2.43 (m, 1H), 2.71 (dd, *J* = 17.5, 2.6 Hz, 1H), 2.80 (dd, *J* = 17.5, 2.6 Hz, 1H), 3.31 (s, 3H), 3.82-3.88 (m, 1H), 4.00-4.05 (m, 1H), 6.07 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.30 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.97 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.20 (dd, *J* = 8.0, 1.1 Hz, 1H), 7.28-7.32 (m, 1H), 7.33-7.37 (m, 2H), 7.77-7.80 (m, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 33.2, 39.4, 41.6, 67.5, 86.0, 100.0, 102.8, 118.4, 124.0, 127.4 (2C), 127.8, 128.3 (2C), 129.4, 130.7, 134.8,

135.2, 142.9, 147.7; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0640.

(*Z*)-6-(4-Chlorophenyl)-11-methyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2k) and 1-(4-Chlorophenyl)-4-methyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3k). According to the procedure described for **Condition A**, **1k** (37.8 mg, 0.117 mmol) was converted into **2k** (27.6 mg, 73%) and **3k** (3.6 mg, <10%) including inseparable impurities by the reaction with $IPrAuNTf_2$ (5.07 mg, 0.00585 mmol) in EtOH (1.2 mL) at 60 ℃ for 30 min. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). According to the procedure described for **Condition B**, **1k** (37.7 mg, 0.117 mmol) was converted into **2k** (2.9 mg, 8%) and **3k** (29.0 mg, 77%) by the reaction with $JohnPhosAuNTf_2$ (4.53 mg, 0.00584 mmol) in *i*-PrOH (1.2 mL) at 80 ℃ for 30 min. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane) and **2k** was purified by PTLC (hexane/EtOAc = 5/1). Compound **2k**: yellow solid; mp 178-180 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.81-2.89 (m, 1H), 3.23-3.32 (m, 2H), 3.45-3.52 (m, 1H), 3.78 (s, 3H), 4.10-4.17 (m, 1H), 4.43-4.50 (m, 1H), 6.25 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.80 (d, *J* = 7.7 Hz, 1H), 6.92 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.17 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.24-7.28 (m, 2H), 7.30-7.36 (m, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.4, 29.8, 63.4, 67.8, 109.1, 110.8, 119.6, 120.2, 121.4, 122.8, 126.3, 128.4 (2C), 129.2 (2C), 133.6, 137.1, 138.9, 139.5, 139.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}ClNO$ 324.1150; found 324.1156. Compound **3k**: yellow solid; mp 168-170 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.00-2.06 (m, 1H), 2.30-2.36 (m, 1H), 2.67 (dd, *J* = 17.5, 2.6 Hz, 1H), 2.72 (dd, *J* = 17.5, 2.6 Hz, 1H), 2.86 (s, 3H), 3.79-3.85 (m, 1H), 4.00-4.05 (m, 1H), 6.07 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.37 (d, *J* = 7.4 Hz, 1H), 6.48 (dd, *J* = 7.4, 7.4 Hz, 1H), 7.03 (d, *J* = 7.4 Hz, 1H), 7.11 (dd, *J* = 7.4, 7.4 Hz, 1H), 7.32 (d, *J* = 8.6 Hz, 2H), 7.76 (d, *J* = 8.6 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 29.7, 38.7, 40.9, 67.9, 85.0, 104.2, 105.8, 116.9, 124.7, 126.9,

128.4 (2C), 128.7 (2C), 129.5, 129.9, 133.3, 133.4, 142.0, 151.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}ClNO$ 324.1150; found 324.1151.

(*Z*)-6-(4-Bromophenyl)-11-methyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2l) and 1-(4-Bromophenyl)-4-methyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3l). According to the procedure described for **Condition A**, **1l** (63.9 mg, 0.174 mmol) was converted into **2l** (36.0 mg, 56%) and **3l** (9.9 mg, <15%) including inseparable impurities by the reaction with $IPrAuNTf_2$ (7.52 mg, 0.00868 mmol) in EtOH (1.7 mL) at 60 ℃ for 30 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). According to the procedure described for **Condition B**, **1l** (38.2 mg, 0.104 mmol) was converted into **2l** (1.4 mg, 4%) and **3l** (26.5 mg, 69%) by the reaction with $JohnPhosAuNTf_2$ (4.03 mg, 0.00519 mmol) in *i*-PrOH (1.0 mL) at 80 ℃ for 5 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). Compound **2l**: white solid; mp 182-184 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.80-2.88 (br m, 1H), 3.22-3.31 (br m, 2H), 3.44-3.52 (br m, 1H), 3.78 (s, 3H), 4.10-4.16 (br m, 1H), 4.42-4.49 (br m, 1H), 6.25 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 6.92 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.17 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.28 (d, *J* = 8.6 Hz, 2H), 7.32 (d, *J* = 8.0 Hz, 1H), 7.41 (d, *J* = 8.6 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.4, 29.8, 63.4, 67.8, 109.1, 110.7, 119.6, 120.2, 121.4, 121.8, 122.8, 126.3, 129.6 (2C), 131.3 (2C), 137.0, 138.9, 139.8, 139.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0641. Compound **3l**: orange solid; mp 169-172 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.00-2.06 (m, 1H), 2.30-2.36 (m, 1H), 2.64-2.74 (m, 2H), 2.86 (s, 3H), 3.80-3.85 (m, 1H), 4.00-4.05 (m, 1H), 6.09 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.37 (d, *J* = 8.0 Hz, 1H), 6.48 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.03 (d, *J* = 8.0 Hz, 1H), 7.12 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.48 (d, *J* = 8.6 Hz, 2H), 7.70 (d, *J* = 8.6 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 29.7, 38.7, 40.9, 67.9, 85.0, 104.2, 105.8, 116.9, 121.7, 124.7, 126.9, 129.0 (2C), 129.6, 129.9, 131.3 (2C),

133.7, 142.0, 151.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}BrNO$ 368.0645; found 368.0645.

(*Z*)-4-(11-Methyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indol-6-yl)benzonitrile (2m) and 4-[4-Methyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indol-1-yl]benzonitrile (3m). According to the procedure described for **Condition A**, **1m** (36.3 mg, 0.116 mmol) was converted into **2m** (26.6 mg, 73%) and **3m** (3.9 mg, <11%) including inseparable impurities by the reaction with $IPrAuNTf_2$ (5.00 mg, 0.00577 mmol) in EtOH (1.2 mL) at 60 ℃ for 30 min. Column chromatography: amine silica gel (gradient 6% to 10% EtOAc in hexane). According to the procedure described for **Condition B**, **1m** (44.3 mg, 0.141 mmol) was converted into **2m** (2.8 mg, 6%) and **3m** (33.0 mg, 74%) by the reaction with $JohnPhosAuNTf_2$ (5.46 mg, 0.00704 mmol) in *i*-PrOH (1.4 mL) at 80 ℃ for 10 min. Column chromatography: amine silica gel (gradient 6% to 20% EtOAc in hexane). Compound **2m**: white solid; IR (neat cm^{-1}): 2226 (C≡N); mp 186-188 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.79-2.90 (br m, 1H), 3.23-3.36 (br m, 2H), 3.47-3.59 (br m, 1H), 3.80 (s, 3H), 4.10-4.19 (br m, 1H), 4.44-4.54 (br m, 1H), 6.33 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.72 (d, *J* = 8.0 Hz, 1H), 6.92 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.18 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.34 (d, *J* = 8.0 Hz, 1H), 7.50 (d, *J* = 8.6 Hz, 2H), 7.58 (d, *J* = 8.6 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.3, 29.8, 63.5, 67.6, 109.3, 110.1, 111.2, 119.0, 119.8 (2C), 121.6, 125.2, 126.0, 128.5 (2C), 132.1 (2C), 137.1, 139.2, 139.4, 145.6; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{19}N_2O$ 315.1492; found 315.1491. Compound **3m**: white solid; IR (neat cm^{-1}): 2245 (C≡N); mp 161-165 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.01-2.07 (m, 1H), 2.32-2.38 (m, 1H), 2.72 (dd, *J* = 18.0, 2.6 Hz, 1H), 2.78 (dd, *J* = 18.0, 2.6 Hz, 1H), 2.87 (s, 3H), 3.81-3.87 (m, 1H), 4.00-4.06 (m, 1H), 6.23 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.39 (d, *J* = 7.7 Hz, 1H), 6.49 (dd, *J* = 7.7, 7.7 Hz, 1H), 6.98 (d, *J* = 7.7 Hz, 1H), 7.13 (dd, *J* = 7.7, 7.7 Hz, 1H), 7.64 (d, *J* = 8.6 Hz, 2H), 7.93 (d, *J* = 8.6 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz,

$CDCl_3$) δ: 29.7, 38.6, 41.1, 68.0, 85.1, 104.1, 106.0, 111.0, 116.9, 119.1, 124.5, 126.6, 127.8 (2C), 130.1, 132.1 (2C), 132.4, 139.4, 141.8, 151.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{19}N_2O$ 315.1492; found 315.1495.

(*Z*)-11-Methyl-6-(*p*-tolyl)-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2n) and 4-Methyl-1-(*p*-tolyl)-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3n). According to the procedure described for **Condition A**, **1n** (60.0 mg, 0.198 mmol) was converted into **2n** (31.5 mg, 53%) and **3n** (7.2 mg, 12%) by the reaction with $IPrAuNTf_2$ (8.57 mg, 0.00989 mmol) in EtOH (2.0 mL) at 60 °C for 1 h, and additional 1 h after addition of a second portion of $IPrAuNTf_2$ (8.57 mg, 0.00989 mmol). Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). According to the procedure described for **Condition B**, **1n** (45.1 mg, 0.149 mmol) was converted into **2n** (4.3 mg, 10%) and **3n** (34.3 mg, 76%) by the reaction with $JohnPhosAuNTf_2$ (5.76 mg, 0.00742 mmol) in *i*-PrOH (1.49 mL) at 80 °C for 5 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). Compound **2n**: white solid; mp 169-172 °C; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.35 (s, 3H), 2.82-2.91 (br m, 1H), 3.21-3.32 (br m, 2H), 3.45-3.52 (br m, 1H), 3.78 (s, 3H), 4.10-4.18 (br m, 1H), 4.43-4.49 (br m, 1H), 6.25 (dd, *J* = 8.3, 8.3 Hz, 1H), 6.84 (d, *J* = 8.0 Hz, 1H), 6.90 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.10 (d, *J* = 8.0 Hz, 2H), 7.15 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.29-7.33 (m, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 21.2, 28.4, 29.7, 63.3, 67.9, 109.0, 111.4, 119.4, 120.4, 121.2, 121.6, 126.6, 127.8 (2C), 128.9 (2C), 137.0, 137.6, 138.1, 138.7, 140.7; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1694. Compound **3n**: colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.99-2.07 (m, 1H), 2.29-2.38 (m, 4H), 2.63-2.74 (m, 2H), 2.86 (s, 3H), 3.80-3.86 (m, 1H), 4.00-4.06 (m, 1H), 6.05 (dd, *J* = 2.3, 2.3 Hz, 1H), 6.36 (d, *J* = 8.0 Hz, 1H), 6.47 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.08-7.13 (m, 2H), 7.17 (d, *J* = 8.0 Hz, 2H), 7.72 (d, *J* = 8.0 Hz, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 21.2, 29.7, 38.8, 40.7, 67.8,

84.9, 104.4, 105.7, 116.8, 124.9, 127.2 (3C), 127.9, 128.9 (2C), 129.7, 131.8, 137.3, 142.8, 151.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1696.

(*Z*)-6-(4-Methoxyphenyl)-11-methyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2o) and 1-(4-Methoxyphenyl)-4-methyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3o). According to the procedure described for **Condition A**, **1o** (55.5 mg, 0.174 mmol) was converted into **2o** (12.4 mg, 22%) and **3o** (7.8 mg, <14%) including inseparable impurities by the reaction with $IPrAuNTf_2$ (7.53 mg, 0.00869 mmol) in EtOH (1.7 mL) at 60 °C for 1 h, and additional 1 h after addition of a second portion of $IPrAuNTf_2$ (7.53 mg, 0.00869 mmol). Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). According to the procedure described for **Condition B**, **1o** (34.9 mg, 0.109 mmol) was converted into **3o** (23.4 mg, 67%) by the reaction with $JohnPhosAuNTf_2$ (4.27 mg, 0.00546 mmol) in *i*-PrOH (1.1 mL) at 80 °C for 5 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). Compound **2o**: yellow solid; mp 144-146 °C; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.83-2.91 (m, 1H), 3.22-3.31 (m, 2H), 3.43-3.50 (m, 1H), 3.78 (s, 3H), 3.81 (s, 3H), 4.11-4.17 (m, 1H), 4.42-4.49 (m, 1H), 6.20 (dd, *J* = 8.3, 8.3 Hz, 1H), 6.81-6.86 (m, 3H), 6.91 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.16 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.32 (d, *J* = 8.0 Hz, 1H), 7.35 (d, *J* = 9.2 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.5, 29.8, 55.2, 63.3, 67.9, 109.0, 111.4, 113.5 (2C), 119.4, 120.4, 120.8, 121.2, 126.6, 129.1 (2C), 133.6, 137.0, 138.7, 140.3, 159.4; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO_2$ 320.1645; found 320.1642. Compound **3o**: yellow oil; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.99-2.06 (m, 1H), 2.30-2.36 (m, 1H), 2.63-2.72 (m, 2H), 2.85 (s, 3H), 3.79-3.85 (m, 4H), 4.01-4.05 (m, 1H), 5.98 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.36 (d, *J* = 8.0 Hz, 1H), 6.47 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.87-6.91 (m, 2H), 7.08-7.12 (m, 2H), 7.77 (d, *J* = 8.6 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 29.7, 38.8, 40.6, 55.2, 67.8,

84.9, 104.4, 105.7, 113.6 (2C), 116.8, 124.8, 126.9, 127.2, 127.4, 128.6 (2C), 129.7, 142.5, 151.9, 159.2; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO_2$ 320.1645; found 320.1641.

(*Z*)-6-(3-Chlorophenyl)-11-methyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2p) and 1-(3-Chlorophenyl)-4-methyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3p). According to the procedure described for **Condition A**, **1p** (43.8 mg, 0.136 mmol) was converted into **2p** (31.1 mg, 71%) and **3p** (2.9 mg, <7%) including inseparable impurities by the reaction with $IPrAuNTf_2$ (5.88 mg, 0.00678 mmol) in EtOH (1.4 mL) at 60 ℃ for 1 h. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). According to the procedure described for **Condition B**, **1p** (47.9 mg, 0.148 mmol) was converted into **2p** (3.8 mg, 8%) and **3p** (35.6 mg, 74%) by the reaction with $JohnPhosAuNTf_2$ (5.75 mg, 0.00742 mmol) in *i*-PrOH (1.5 mL) at 80 ℃ for 1 h. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). Compound **2p**: yellow solid; mp 171-174 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.80-2.90 (br m, 1H), 3.22-3.33 (br m, 2H), 3.44-3.53 (br m, 1H), 3.78 (s, 3H), 4.10-4.18 (br m, 1H), 4.42-4.51 (br m, 1H), 6.25 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.81 (d, *J* = 8.0 Hz, 1H), 6.92 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.17 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.19-7.23 (m, 1H), 7.25-7.28 (m, 2H), 7.32 (d, *J* = 8.0 Hz, 1H), 7.40-7.43 (m, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.4, 29.8, 63.4, 67.7, 109.1, 110.7, 119.7, 120.1, 121.4, 123.5, 126.3 (2C), 127.8 (2C), 129.4, 134.1, 137.1, 138.9, 139.8, 143.1; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}ClNO$ 324.1150; found 324.1146. Compound **3p**: yellow oil; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.00-2.06 (m, 1H), 2.30-2.36 (m, 1H), 2.68 (dd, *J* = 17.8, 2.9 Hz, 1H), 2.73 (dd, *J* = 17.8, 2.9 Hz, 1H), 2.86 (s, 3H), 3.80-3.86 (m, 1H), 4.00-4.05 (m, 1H), 6.11 (dd, *J* = 2.9, 2.9 Hz, 1H), 6.37 (d, *J* = 8.0 Hz, 1H), 6.49 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.05 (d, *J* = 8.0 Hz, 1H), 7.12 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.25-7.31 (m, 2H), 7.71-7.74 (m, 1H), 7.79-7.82 (m, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 29.7, 38.7, 40.9, 67.8, 85.0, 104.2, 105.8, 116.9, 124.7, 125.5,

126.8, 127.4, 127.7, 129.5, 129.9, 130.3, 134.2, 136.7, 141.9, 151.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}ClNO$ 324.1150; found 324.1148.

(*E*)-6-(2-Chlorophenyl)-11-methyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2q) and 1-(2-Chlorophenyl)-4-methyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3q). According to the procedure described for **Condition A**, **1q** (47.2 mg, 0.146 mmol) was converted into **2q** (33.2 mg, 70%) and **3q** (5.7 mg, <12%) including inseparable impurities by the reaction with $IPrAuNTf_2$ (6.34 mg, 0.00731 mmol) in EtOH (1.5 mL) at 60 ℃ for 1h. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). According to the procedure described for **Condition B**, **1q** (40.9 mg, 0.127 mmol) was converted into **2q** (11.1 mg, 27%) and **3q** (10.8 mg, 26%) by the reaction with $JohnPhosAuNTf_2$ (4.91 mg, 0.00633 mmol) in *i*-PrOH (1.3 mL) at 80 ℃ for 3 h. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). Compound **2q**: white solid; mp 149-151 ℃; ^{1}H NMR (500 MHz, DMSO-d_6, 100 ℃) δ: 3.12-3.16 (br m, 2H), 3.70-3.76 (m, 5H), 4.00-4.04 (br m, 2H), 5.83 (dd, *J* = 7.2, 7.2 Hz, 1H), 6.62 (d, *J* = 8.0 Hz, 1H), 6.74 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.01 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.29-7.37 (m, 4H), 7.42 (dd, *J* = 8.0, 1.7 Hz, 1H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 28.5, 29.8, 63.2, 67.4, 109.0, 111.5, 119.3, 119.6, 121.2, 125.6, 126.2, 126.5, 128.6, 129.9, 131.5, 133.5, 136.8, 138.0, 139.6, 141.2; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}ClNO$ 324.1150; found 324.1149. Compound **3q**: yellow oil; ^{1}H-NMR (500 MHz, $CDCl_3$) δ: 2.10-2.16 (m, 1H), 2.23-2.30 (m, 1H), 2.67 (dd, *J* = 17.8, 2.3 Hz, 1H), 2.88-2.94 (m, 4H), 3.84-3.89 (m, 1H), 4.00-4.06 (m, 1H), 6.10 (dd, *J* = 2.3, 2.3 Hz, 1H), 6.38 (d, *J* = 8.0 Hz, 1H), 6.46 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.68 (d, *J* = 8.0 Hz, 1H), 7.11 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.23 (ddd, *J* = 7.7, 7.7, 1.7 Hz, 1H), 7.28 (ddd, *J* = 7.7, 7.7, 1.1 Hz, 1H), 7.39 (dd, *J* = 7.7, 1.1 Hz, 1H), 7.84 (dd, *J* = 7.7, 1.7 Hz, 1H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 29.8, 38.9, 42.3, 67.3, 84.0, 105.5, 105.8, 116.9, 124.3, 126.1, 127.0, 128.4, 129.6, 129.9, 130.8, 133.7, 134.2,

134.4, 138.4, 151.5; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{20}H_{19}ClNO$ 324.1150; found 324.1152.

(*Z*)-11-Methyl-6-(naphthalen-2-yl)-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2r) and 4-Methyl-1-(naphthalen-2-yl)-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3r). According to the procedure described for **Condition A**, **1r** (32.0 mg, 0.0943 mmol) was converted into **2r** (20.0 mg, 63%) and **3r** (2.8 mg, <9%) including inseparable impurities by the reaction with $IPrAuNTf_2$ (4.09 mg, 0.00474 mmol) in EtOH (0.9 mL) at 60 ℃ for 9 h. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane) and **3r** was purified by PTLC (hexane/acetone = 5/1). According to the procedure described for **Condition B**, **1r** (39.2, mg, mmol) was converted into **3r** (20.2 mg, 52%) by the reaction with $JohnPhosAuNTf_2$ (4.48 mg, 0.00577 mmol) in *i*-PrOH (1.2 mL) at 80 ℃ for 5 h. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). Compound **2r**: yellow solid; mp 190-193 ℃; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.89-2.97 (br m, 1H), 3.26-3.37 (br m, 2H), 3.51-3.60 (br m, 1H), 3.82 (s, 3H), 4.13-4.21 (br m, 1H), 4.49-4.56 (br m, 1H), 6.41 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.77-6.85 (m, 2H), 7.12-7.17 (m, 1H), 7.33 (d, *J* = 8.6 Hz, 1H), 7.40-7.47 (m, 2H), 7.55 (dd, *J* = 8.0, 1.7 Hz, 1H), 7.73-7.78 (m, 2H), 7.80-7.84 (m, 1H), 7.89 (s, 1H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 28.5, 29.8, 63.4, 67.9, 109.0, 111.3, 119.6, 120.4, 121.3, 123.1, 125.8, 125.9, 126.2, 126.6, 127.0, 127.5, 127.7, 128.3, 133.1, 133.4, 137.1, 138.6, 138.9, 140.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{24}H_{21}NO$ 340.1696; found 340.1699. Compound **3r**: yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.03-2.11 (m, 1H), 2.34-2.40 (m, 1H), 2.73 (dd, *J* = 17.5, 2.6 Hz, 1H), 2.78 (dd, *J* = 17.5, 2.6 Hz, 1H), 2.88 (s, 3H), 3.86-3.92 (m, 1H), 4.08-4.13 (m, 1H), 6.24 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.38 (d, *J* = 8.0 Hz, 1H), 6.42 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.10 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.13 (d, *J* = 8.0 Hz, 1H), 7.43-7.50 (m, 2H), 7.78-7.87 (m, 3H), 7.91 (d, *J* = 6.9 Hz, 1H), 8.43 (s, 1H); ^{13}C{^{1}H} NMR

(125 MHz, $CDCl_3$) δ: 29.8, 38.8, 40.8, 68.0, 85.1, 104.5, 105.8, 116.9, 125.0, 125.5, 125.9, 126.0, 126.3, 127.2, 127.5, 127.8, 128.5, 129.4, 129.8, 132.1, 132.9, 133.4, 143.1, 151.9; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{24}H_{21}NO$ 340.1696; found 340.1697.

(*Z*)-6,11-Dimethyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2s) and 1,4-Dimethyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3s). To a stirred mixture of **1s** (31.7 mg, 0.139 mmol) in *i*-PrOH was added MS3Å at room temperature. After the mixture was stirred for 30 min at this temperature, $IPrAuNTf_2$ (6.04 mg, 0.0697 mmol) was added to the mixture. After being stirred for 10 h at 80 ℃, the reaction mixture was filtered through a short pad of celite and silica gel, and the filtrate was evaporated in vacuo to give a crude product, which was purified by PTLC (hexane/acetone = 5/1) and PTLC (toluene/EtOAc = 5/1) to give **2s** (5.1 mg, 16%) and **3s** (2.5 mg, 8%). According to the procedure described for **Condition B**, **1s** (46.1 mg, 0.203 mmol) was converted into **2s** (2.4 mg, 5%) and **3s** (15.5 mg, 34%) by the reaction with $JohnPhosAuNTf_2$ (7.86 mg, 0.0101 mmol) in *i*-PrOH (2.0 mL) at 80 ℃ for 30 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexane). **Condition C:** To a stirred mixture of **1s** (22.6 mg, 0.0994 mmol) in DCE (0.99 mL) was added 5 mol % $IPrAuNTf_2$ (4.31 mg, 0.0497 mmol) at room temperature. After being stirred for 10 min at 80 ℃, the reaction mixture was filtered through a short pad of celite and silica gel, and the filtrate was evaporated in vacuo to give a crude product, which was purified by PTLC (hexane/acetone = 5/1) to give **2s** (trace) and **3s** (18.5 mg, 82%). Compound **2s**: orange solid; mp 93-95 ℃; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.30 (s, 3H), 2.67-2.86 (br m, 1H), 3.08-3.28 (br m, 2H), 3.29-3.43 (br m, 1H), 3.72 (s, 3H), 4.02-4.16 (br m, 1H), 4.20-4.33 (br m, 1H), 5.85 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.12 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.22 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.32 (d, *J* = 8.0 Hz, 1H), 7.62 (d, *J* = 8.0 Hz, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 23.3, 28.4, 29.7, 63.6, 67.6, 109.2, 113.4, 119.5, 119.7, 121.2, 122.4, 126.1, 136.8, 136.9, 137.3;

HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{15}H_{18}NO$ 228.1383; found 228.1381. Compound **3s**: ^1H NMR (500 MHz, $CDCl_3$) δ: 1.93 (d, *J* = 1.1 Hz, 3H), 1.94-1.98 (m, 1H), 2.19-2.24 (m, 1H), 2.42-2.46 (m, 1H), 2.58-2.62 (m, 1H), 2.83 (s, 3H), 3.71-3.75 (m, 1H), 3.85-3.89 (m, 1H), 5.42 (m, 1H), 6.36 (dd, *J* = 8.0, 1.1 Hz, 1H), 6.64 (ddd, *J* = 7.7, 7.4, 1.1 Hz, 1H), 7.15 (ddd, *J* = 8.0, 7.7, 1.1 Hz, 1H), 7.29 (dd, *J* = 7.4, 1.1 Hz, 1H). The ^1H NMR spectra were in good agreement with those reported.[9]

(*Z*)-6-Phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2t) and 1-Phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3t). According to the procedure described for **Condition A**, **1t** (42.0 mg, 0.153 mmol) was converted into **2t** (13.3 mg, 32%) and **3t** (2.8 mg, 7%) by the reaction with $IPrAuNTf_2$ (6.61 mg, 0.00763 mmol) in EtOH (1.5 mL) at 60 ℃ for 9 h. Column chromatography: amine silica gel (gradient 4% to 40% EtOAc in hexane) and **3t** was purified by PTLC (hexane/Acetone = 5/1). According to the procedure described for **Condition B**, **1t** (48.4 mg, 0.176 mmol) was converted into **3t** (8.6 mg, 18%) by the reaction with $JohnPhosAuNTf_2$ (6.82 mg, 0.00879 mmol) in *i*-PrOH (1.8 mL) at 80 ℃ for 6 h. Column chromatography: amine silica gel (gradient 4% to 15% EtOAc in hexane). Compound **2t**: orange oil; ^1H NMR (500 MHz, DMSO-d_6, 100 ℃) δ: 2.94 (t, *J* = 4.6 Hz, 2H), 3.60 (s, 2H), 3.88 (s, 2H), 6.13 (t, *J* = 8.0 Hz, 1H), 6.56 (d, *J* = 8.0 Hz, 1H), 6.73 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.97 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.27-7.34 (m, 6H), 10.95 (s, 1H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 31.4, 63.9, 68.0, 110.5, 111.7, 119.8, 120.4, 121.7, 122.7, 127.7, 127.8, 128.0 (2C), 128.2 (2C), 135.3, 137.3, 140.6, 140.8; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{19}H_{18}NO$ 276.1383; found 276.1383. Compound **3t**: colorless oil; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.19-2.25 (m, 1H), 2.28-2.33 (m, 1H), 2.72 (dd, *J* = 17.5, 2.6 Hz, 1H), 2.93 (dd, *J* = 17.5, 2.6 Hz, 1H), 3.84-3.91 (m, 1H), 4.03-4.08 (m, 1H), 4.14 (s, 1H), 6.09 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.56 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.59 (d, *J* = 8.0 Hz, 1H), 7.06 (dd, *J* = 8.0, 8.0

Hz, 1H), 7.12 (d, *J* = 8.0 Hz, 1H), 7.28-7.32 (m, 1H), 7.34-7.39 (m, 2H), 7.84 (d, *J* = 7.4 Hz, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 43.0, 46.2, 67.7, 80.1, 106.3, 109.7, 118.8, 125.2, 127.4 (2C), 127.6, 127.8, 128.2 (2C), 129.3, 129.6, 134.8, 143.0, 151.3; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{19}H_{18}NO$ 276.1383; found 276.1380.

(*Z*)-11-Benzyl-6-methyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2u) and 4-Benzyl-1-methyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3u). According to the procedure described for **Condition A**, **1u** (52.6 mg, 0.144 mmol) was converted into **2u** (29.6 mg, 56%) and **3u** (trace) by the reaction with $IPrAuNTf_2$ (6.24 mg, 0.00720 mmol) in EtOH (1.4 mL) at 60 ℃ for 30 min. Column chromatography: amine silica gel (gradient 2% to 5% EtOAc in hexanes) and amine PTLC(hexane/EtOAc = 5/1). According to the procedure described for **Condition B**, **1u** (51.0 mg, 0.140 mmol) was converted into **2u** (4.0 mg, 8%) and **3u** (39.5 mg, 77%) by the reaction with $JohnPhosAuNTf_2$ (5.41 mg, 0.00698 mmol) in *i*-PrOH (1.4 mL) at 80 ℃ for 10 min. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexanes). Compound **2u**: white solid; mp 150-152 ℃; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.77-2.87 (br m, 1H), 2.90-2.99 (br m, 1H), 3.10-3.19 (br m, 1H), 3.43-3.52 (br m, 1H), 3.88-3.96 (br m, 1H), 4.41-4.50 (br m, 1H), 5.37-5.48 (m, 2H), 6.29 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.85 (d, *J* = 7.4 Hz, 1H), 6.91 (t, *J* = 7.4 Hz, 1H), 7.04 (d, *J* = 7.4 Hz, 2H), 7.12 (dd, *J* = 7.4, 7.4 Hz, 1H), 7.26-7.35 (m, 7H), 7.41-7.45 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 28.5, 46.6, 63.2, 67.8, 109.4, 112.0, 119.8, 120.5, 121.7, 122.7, 126.0 (2C), 126.7, 127.6, 127.8, 128.0 (2C), 128.2 (2C), 129.0 (2C), 137.0, 137.7, 138.7, 140.6, 141.0; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{26}H_{24}NO$ 366.1852; found 366.1854. Compound **3u**: yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.02-2.09 (m, 1H), 2.29-2.36 (m, 1H), 2.69-2.79 (m, 2H), 3.91-3.98 (m, 1H), 4.04-4.09 (m, 1H), 4.42-4.50 (m, 2H), 6.10 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.21 (d, *J* = 8.0 Hz, 1H), 6.48 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.00 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.12 (d, *J* = 8.0

Hz, 1H), 7.25-7.40 (m, 8H), 7.86 (d, J = 7.4 Hz, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 39.9, 41.9, 49.2, 67.9, 85.4, 104.6, 106.7, 117.2, 124.9, 126.7 (2C), 127.0, 127.3, 127.4 (2C), 127.7, 128.2 (2C), 128.6 (3C), 129.7, 134.7, 138.9, 143.2, 151.7; HRMS (ESI-TOF) m/z: $[M + H]^+$ calcd for $C_{26}H_{24}NO$ 366.1852; found 366.1851.

10-Methyl-5-phenyl-3,10-dihydro-1*H*-oxepino[3,4-*b*]indole (2v). According to the procedure described for **Condition A**, **1v** (50.8 mg, 0.184 mmol) was converted into **2v** (31.8 mg, 63%) by the reaction with $IPrAuNTf_2$ (8.00 mg, 0.00922 mmol) in EtOH (1.8 mL) at 60 °C 5 h. Column chromatography: amine silica gel (gradient 4% to 10% EtOAc in hexanes). According to the procedure described for **Condition B**, **1v** (28.8 mg, 0.105 mmol) was converted into **2v** (12.7 mg, 44%) by the reaction with $JohnPhosAuNTf_2$ (4.06 mg, 0.00523 mmol) in *i*-PrOH (1.0 mL) at 80 °C for 9 h. Column chromatography: amine silica gel (gradient 2% to 10% EtOAc in hexanes). Compound **2v**: orange oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 3.81 (s, 3H), 4.03 (d, J = 6.9 Hz, 2H), 4.80 (s, 2H), 6.31 (t, J = 6.9 Hz, 1H), 6.79 (d, J = 8.0 Hz, 1H), 6.92 (dd, J = 8.0, 8.0 Hz, 1H), 7.21 (dd, J = 8.0, 8.0 Hz, 1H), 7.33-7.38 (m, 4H), 7.42-7.47 (m, 2H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$) δ: 29.9, 61.2, 64.4, 109.5, 114.4, 119.7, 121.1, 122.0, 123.4, 125.4, 127.9, 128.2 (2C), 128.3 (2C), 137.4, 140.0, 140.2, 144.0; HRMS (ESI-TOF) m/z: $[M + H]^+$ calcd for $C_{19}H_{18}NO$ 276.1383; found 276.1387.

5-Methyl-10-phenyl-3,4-dihydro-2*H*,5*H*-9b,4a-prop[1]enopyrano[3,2-*b*]indole (3w). The reaction of **1w** (40.8 mg, 0.134 mmol) with $IPrAuNTf_2$ (5.21 mg, 0.00672 mmol) in EtOH (1.3 mL) under **condition A** gave a mixture of unidentified products without producing **2w**/**3w**. According to the procedure described for **Condition B**, **1w** (40.7 mg, 0.134 mmol) was converted into **3w** (11.4 mg, 28%) by the reaction with $JohnPhosAuNTf_2$ (5.20 mg, 0.00671 mmol) in *i*-PrOH (1.3 mL) at 80 °C for 7 h. Column chromatography: amine silica gel (gradient 2% to 5%

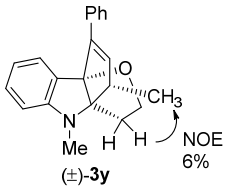
EtOAc in hexane). Compound **3w**: blue oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ: 1.50-1.57 (m, 1H), 1.63-1.70 (m, 1H), 1.77-1.83 (m, 1H), 1.96-2.02 (m, 1H), 2.42 (dd, *J* = 16.9, 2.6 Hz, 1H), 2.46 (dd, *J* = 16.9, 2.6 Hz, 1H), 2.77 (s, 3H), 3.58-3.68 (m, 2H), 6.33 (dd, *J* = 2.6, 2.6 Hz, 1H), 6.48 (d, *J* = 7.4 Hz, 1H), 6.59 (dd, *J* = 7.4, 7.4 Hz, 1H), 7.10-7.15 (m, 2H), 7.24-7.28 (m, 1H), 7.30-7.35 (m, 2H), 7.80 (d, *J* = 6.9 Hz, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 20.4, 26.4, 29.4, 39.5, 61.0, 74.3, 93.5, 107.2, 117.8, 124.6, 127.2 (2C), 127.4 (2C), 128.1 (2C), 129.3, 130.0, 135.0, 142.7, 151.7; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1698.

(*Z*)-11-Methyl-6-phenyl-3-tosyl-2,3,4,11-tetrahydro-1*H*-azocino[4,5-*b*]indole (2x). According to the procedure described for **Condition A**, **1x** (49.1 mg, 0.111 mmol) was converted into **2x** (30.9 mg, 63%) by the reaction with $IPrAuNTf_2$ (4.81 mg, 0.00555 mmol) in EtOH (1.1 mL) at 60 °C 3.5 h. Column chromatography: amine silica gel (gradient 6% to 18% EtOAc in hexane). According to the procedure described for **Condition B**, **1x** (48.5 mg, 0.110 mmol) was converted into **2x** (32.5 mg, 67%) by the reaction with $JohnPhosAuNTf_2$ (4.25 mg, 0.00548 mmol) in *i*-PrOH (1.1 mL) at 80 °C for 20 min. Column chromatography: amine silica gel (gradient 6% to 25% EtOAc in hexane). Compound **2x**: white solid; mp 163-166 °C; IR (neat cm^{-1}): 1333 (S=O), 1157 (S=O); ^{1}H NMR (500 MHz, $CDCl_3$) δ: 2.37 (s, 3H), 2.62-2.70 (br m, 1H), 2.81-2.89 (br m, 1H), 2.90-2.96 (br m, 1H), 3.27-3.33 (br m, 1H), 3.71 (s, 3H), 4.01-4.08 (br m, 1H), 4.34-4.40 (br m, 1H), 6.30 (dd, *J* = 8.0, 8.0 Hz, 1H), 6.79 (d, *J* = 8.0 Hz, 1H), 6.87 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.13 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.21-7.30 (m, 6H), 7.34-7.38 (m, 2H), 7.67 (d, *J* = 8.0 Hz, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$) δ: 21.4, 26.1, 29.7, 43.1, 47.2, 109.0, 111.4, 119.6, 120.3, 121.5, 121.6, 126.4, 127.0 (2C), 127.7 (2C), 127.8, 128.1 (2C), 129.7 (2C), 136.5, 137.0, 137.2, 140.4 (2C), 143.2; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{27}H_{27}N_2O_2S$ 443.1788; found 443.1787.

2-[1-Methyl-3-(1-phenylpropa-1,2-dien-1-yl)-1*H*-indol-2-yl]ethan-1-ol (4a). To a stirred mixture of **1a** (19.0 mg, 0.0657 mmol) in *i*-PrOH (0.66 mL) was added 5 mol % JohnPhosAuNTf$_2$ (2.55 mg, 0.00328 mmol) at room temperature. After being stirred for 5 min at 40 ℃, the reaction mixture was filtered through a short pad of celite and silica gel, and the filtrate was evaporated in vacuo to give a crude product, which was purified by PTLC (hexane/acetone = 5/1) to give **4a** (6.6 mg, 35%), **2a** (2.6 mg, 14%) and **3a** (8.8 mg, 46%). Compound **4a**: brown oil; IR (neat cm^{-1}): 3348 (OH), 1933 (C=C=C); ^{1}H NMR (500 MHz,CDCl$_3$) δ: 1.48 (t, *J* = 5.4 Hz, 1H), 3.08 (t, *J* = 6.9 Hz, 2H), 3.80 (s, 3H), 3.83 (dt, *J* = 5.4, 6.9 Hz, 2H), 5.19 (s, 2H), 7.01 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.17-7.24 (m, 3H), 7.25-7.29 (m, 2H), 7.30-7.36 (m, 3H); ^{13}C{^{1}H} NMR (125 MHz, CDCl$_3$) δ: 28.5, 30.1, 61.9, 76.7, 101.2, 107.9, 109.0, 119.5, 119.7, 121.4, 126.9, 127.0 (2C), 127.2, 128.3 (2C), 135.2, 136.5, 137.2, 210.1; HRMS (ESI-TOF) *m*/*z*: [M + H]$^+$ calcd for C$_{20}$H$_{20}$NO 290.1539; found 290.1530.

(*Z*)-4,11-Dimethyl-6-phenyl-1,2,4,11-tetrahydrooxocino[4,5-*b*]indole (2y) and 3,4-Dimethyl-1-phenyl-3*H*,4*H*-8b,3a-(epoxyethano)cyclopenta[*b*]indole (3y). According to the procedure described for **Condition B**, (*S*)-**1y** (14.9 mg, 0.0491 mmol; >99% ee) was converted into **2y** (5.2 mg, 35%; 0% ee) and **3y** (5.2 mg, 35%; 0% ee) by the reaction with IPrAuNTf$_2$ (2.13 mg, 0.00246 mmol) in EtOH (0.49 mL) at 60 ℃ for 5 h. PTLC: amine silica gel (hexane/acetone = 5/1) and amine silica gel (hexane/EtOAc = 5/1). Compound **2y**: white solid; mp 164-166 ℃; ^{1}H NMR (500 MHz, CDCl$_3$) δ: 1.35 (d, *J* = 6.3 Hz, 3H), 2.81-2.88 (m, 1H), 3.25-3.31 (m, 1H), 3.39-3.46 (m, 1H), 3.66-3.74 (m, 1H), 3.78 (s, 3H), 4.20-4.26 (m, 1H), 5.93 (d, *J* = 8.6 Hz, 1H), 6.81 (d, *J* = 8.0 Hz, 1H), 6.89 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.15 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.27-7.32 (m, 4H), 7.39-7.43 (m, 2H); ^{13}C{^{1}H} NMR (125 MHz, CDCl$_3$) δ: 23.2, 28.8, 29.7, 63.4, 72.9, 109.0, 111.6, 119.4, 120.4, 121.2, 126.6, 127.6, 127.9 (2C), 128.2 (2C), 128.9, 137.0, 138.2, 138.6, 140.9;

HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1692. Compound **3y**: yellow oil; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.27 (d, *J* = 7.4 Hz, 3H), 2.05-2.10 (m, 1H), 2.12-2.18 (m, 1H), 2.85-2.90 (m, 4H), 3.81-3.87 (m, 1H), 4.04-4.08 (m, 1H), 5.99 (d, *J* = 2.3 Hz, 1H), 6.39 (d, *J* = 7.4 Hz, 1H), 6.48 (dd, *J* = 7.4, 7.4 Hz, 1H), 7.09 (d, *J* = 7.4 Hz, 1H), 7.12 (dd, *J* = 7.4, 7.4 Hz, 1H), 7.27-7.32 (m, 1H), 7.33-7.38 (m, 2H), 7.86 (d, *J* = 7.4 Hz, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$) δ: 16.5, 29.8, 32.9, 43.3, 68.7, 87.8, 104.3, 105.9, 116.9, 124.9, 127.3, 127.5 (2C), 127.7, 128.3 (2C), 129.8, 134.4, 134.8, 141.5, 151.7; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1696. The relative configuration of **3y** was determined by NOE analysis.



2-(1-Methyl-3-(1-phenylbuta-1,2-dien-1-yl)-1*H*-indol-2-yl)ethan-1-ol (4y) To a stirred mixture of (*S*)-**1y** (16.5 mg, 0.0544 mmol; >99% ee) in EtOH (0.54 mL) was added 5 mol % $IPrAuNTf_2$ (2.36 mg, 0.00272 mmol) at 60 ℃. After being stirred for 1 h at 60 ℃, the reaction mixture was filtered through a short pad of celite and silica gel, and the filtrate was evaporated in vacuo to give a crude product, which was purified by PTLC (hexane/acetone = 5/1) to give **4y** (6.2 mg, <38%) including inseparable impurities, **2y** (2.7 mg, 16%) and **3y** (2.5 mg, <15%) including inseparable impurities. Compound **4y**: brown oil; IR (neat cm^{-1}): 3397 (OH), 2128 (C=C=C); ^1H NMR (500 MHz,$CDCl_3$) δ: 1.84 (d, *J* = 7.4 Hz, 3H), 3.08 (t, *J* = 6.9 Hz, 2H), 3.78-3.84 (m, 5H), 5.58 (q, *J* = 7.4 Hz, 1H), 7.01 (dd, *J* = 8.0, 8.0 Hz, 1H), 7.16-7.22 (m, 3H), 7.23-7.27 (m, 2H), 7.30-7.35 (m, 3H); $^{13}C\{^1H\}$ NMR (150 MHz, $CDCl_3$) δ: 14.5, 28.5, 30.1, 62.1, 87.3, 100.9, 109.0

(2C), 119.4, 119.8, 121.3, 126.7, 127.1 (2C), 127.3, 128.2 (2C), 135.0, 137.1, 137.6, 206.6; HRMS (ESI-TOF) *m*/*z*: $[M + H]^+$ calcd for $C_{21}H_{22}NO$ 304.1696; found 304.1697.

ASSOCIATED CONTENT

Supporting Information.

HPLC chromatograms, NMR spectra and synthetic schemes. The Supporting Information is available free of charge on the ACS Publications website at DOI:

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Notes

The authors declare no comprting financial interest.

ACKNOWLEDGMENTS

This work was supported by the JSPS KAKENHI (Grant Numbers JP18H04615, JP18H04408 and JP17H03971), by the Platform Project for Supporting Drug Discovery and Life Science Research (Platform for Drug Discovery, Informatics, and Structural Life Science) from the Japan Agency

for Medical Research and Development (AMED), (Grant Numbers JP18gm1010007 and JP18ak0101072), and by the Uehara Memorial Foundation.

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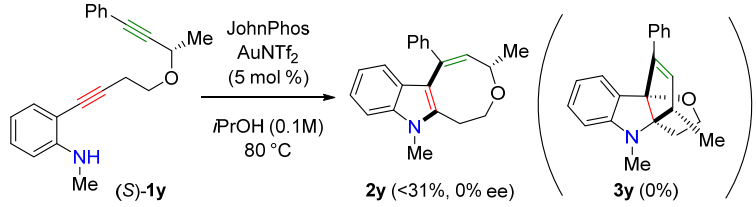
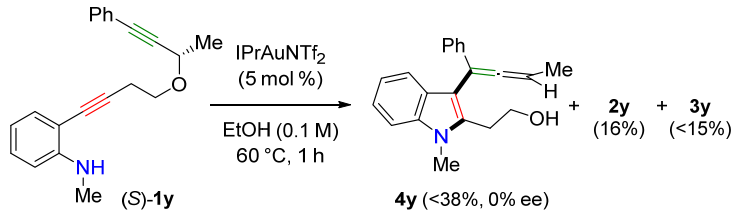
(10) The indole immediate resulting from the first cyclization was detected.

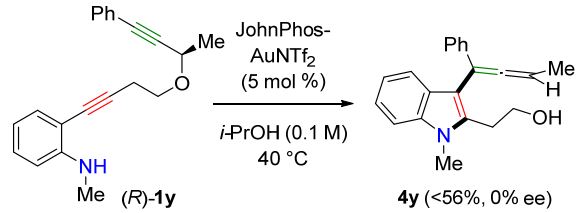
(11) Some unidentified side products were observed along with the desired indole **2o**, implying that the product **2o** bearing an electron-rich aryl group, or the reaction intermediates would be unstable under the condition.

(12) The reaction of **1y** under condition B (5 mol % JohnPhosAuNTf$_2$, 0.1M in *i*PrOH, 80 °C) gave the indole **2y** (<31%, 0% ee).



(13) Isolation of allene **4y** and determination of the enantiomeric excess of **4y**.





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