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Mechanistic Dichotomy with Alkynes in the Formal Hydrohydrazination/Fischer Indolization Tandem Reaction Catalyzed by a $Ph_3PAuNTf_2$/*p*TSA Binary System

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An efficient method involving a formal hydrohydrazination/Fischer indolization tandem reaction to synthesize 2,3-disubstituted indoles from alkynes and arylhydrazines has been developed. The approach uses a $Ph_3PAuNTf_2$/*p*TSA·H_2O binary catalytic system in which a very low catalyst loading of $Ph_3PAuNTf_2$ (2 mol-%) is required. The reaction time is very short and, most importantly, the reaction is not sensitive to moisture. The mechanism of these reactions has been investigated and the results led us to propose an interesting mechanistic dichotomy. When alkynes have OH/COOH groups in the tether, hydroalkoxylation/hydrocarboxylation occurred to generate exocyclic enol ethers/lactones that reacted with hydrazines to produce indoles. In cases where the alkynes lack OH/COOH groups, hydration occurs to generate ketones that react with arylhydrazines to give the desired indoles.

Introduction

Indole derivatives have been widely applied in medicinal chemistry due to their widespread occurrence in nature and because of their remarkable biological activities.[1] Selected examples of indole-containing pharmaceuticals are given in Figure 1. The synthesis of indoles has been the object of research for over a century, and a variety of well-established classical methods are now available in the literature.[2] Among the various approaches, transition-metal-catalyzed reactions are the most attractive because the reactions can lead directly to the construction of multiply-substituted indoles from readily accessible starting materials under mild conditions.[3] One of the ways to access indoles is the metal-mediated domino hydrohydrazination–Fischer indolization reaction between arylhydrazines and alkynes,[4] however, a major limitation of this method is the use of moisture-sensitive titanium complexes and the acid catalyst is often needed to be introduced into the reaction mixture in a stepwise manner. Recently, Beller and co-workers reported an excellent method for the one-pot synthesis of 2,3-disubstituted indoles from arylhydrazines and terminal alkynes using Zn^{II} salts.[5] However, a stoichiometric amount of catalyst and a longer reaction time (24 h) was required for the reaction to reach completion. Moreover, the reactivity of internal alkynes was not reported. Therefore, an efficient and general method for the synthesis of indoles from alkynes and arylhydrazines, which addresses the above issues, is still highly desirable.

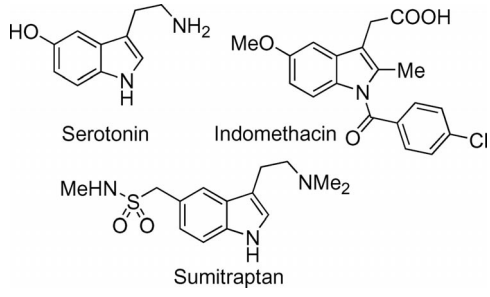

Figure 1. Structures of indole-based pharmaceuticals.

The development of π-acid-catalyzed transformations that allow the rapid construction of heterocyclic scaffolds from simple and readily accessible starting materials constitutes an ongoing challenge in synthetic organic chemistry.[6] One of the most effective ways to achieve this goal can be to implement a reaction cascade involving mechanistically distinct catalytic cycles assisted by different catalysts in one pot.[7] The major challenge in developing a multiple catalyst system is that each catalyst must be compatible with the other as well as with reagents and intermediates generated in the reaction mixture.[8] In recent years, the concept of combining transition-metal catalysis with organocatalysis has emerged as a promising strategy for developing such unique transformations. More particularly, the combination of a metal complex with a Brønsted acid has led to the discovery of many unprecedented transformations,[9] including asymmetric versions.[10]

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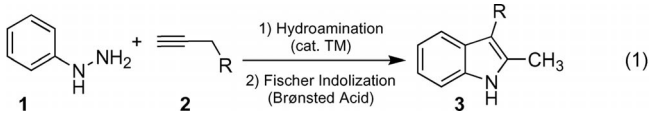
As part of our ongoing program on alkyne activation,[11] we envisioned a one-pot process consisting of catalytic amounts of metal and Brønsted acid for the synthesis of 2,3-disubstituted indoles, as shown in Equation (1). Herein, we wish to report our findings, namely, an efficient formal hydrohydrazination–Fischer indolization tandem reaction for the synthesis of 2,3-disubstituted indoles using a $Ph_3PAuNTf_2$/*p*TSA·H_2O binary catalytic system. The method was found to be very general and demonstrated that $Ph_3PAuNTf_2$ and *p*TSA·H_2O are compatible with each other, even at high temperature. Furthermore, while studying the mechanism of the reaction, we observed an interesting mechanistic dichotomy that was found to be dependent on the type of alkyne used.



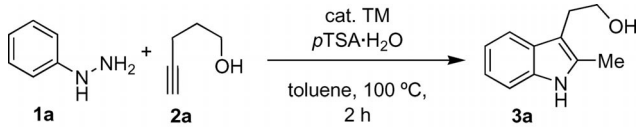
(1)

Results and Discussion

Previously, the use of *p*TSA·H_2O was reported for Fischer indolization from the corresponding arylhydrazones.[12] Thus, we initiated our research by finding a suitable metal catalyst that would be compatible with *p*TSA·H_2O at elevated temperatures. The reactions were performed in the non-polar and non-coordinating solvent toluene, and the results are summarized in Table 1. The reaction was conducted between phenylhydrazine (**1a**) and 4-pentyn-1-ol (**2a**) in the presence of 5 mol-% $PtCl_2$ and 1.1 equiv. *p*TSA·H_2O in toluene at 100 °C (Table 1, entry 1). To our delight, product **3a** was obtained in 40% yield as a single regioisomer.[13] Under the same reaction conditions, the use of $PtCl_4$ as catalyst afforded **3a** in 70% yield (Table 1, entry 2). On the other hand, use of either AgOTf or $Cu(OTf)_2$ as catalyst gave inferior results (Table 1, entries 3 and 4). The catalyst AuCl gave **3a** in 80% yield (Table 1, entry 5). To optimize the reaction further, we examined other Au^I complexes, such as $Ph_3PAuOTf$ (Table 1, entry 6) and $Ph_3PAuNTf_2$ (Table 1, entry 7); out of these, the latter complex proved to be the best, giving **3a** in 92% yield. Lowering catalyst loading to 2 mol-% did not have an adverse effect on the yield of product **3a** (Table 1, entry 8). The reaction between **1a** and **2a** in the presence of 10 mol-% Tf_2NH did not give indole **3a**, which clearly indicates that the $Ph_3PAuNTf_2$ catalyst is responsible for the reaction (Table 1, entry 9). The reaction did not lead to the formation of the desired product **3a** in the absence of either of the catalysts (Table 1, entries 10 and 11).

We then considered the possibility that the NTf_2 counter anion might be replaced by the OTs group under the present reaction conditions and that, therefore, the actual catalyst could be $Ph_3PAuOTs$. In this context, an experiment was conducted to establish the catalytic activity of $Ph_3PAuOTs$ (Table 1, entry 12). Interestingly, the formation of

Table 1. Examination of catalysts.[a]



Entry	Metal catalyst	Brønsted acid	Yield[b]
1	5 mol-% $PtCl_2$	*p*TSA·H_2O	40%
2	5 mol-% $PtCl_4$	*p*TSA·H_2O	70%
3	5 mol-% AgOTf	*p*TSA·H_2O	–%[c]
4	5 mol-% $Cu(OTf)_2$	*p*TSA·H_2O	20%
5	5 mol-% AuCl	*p*TSA·H_2O	80%
6	5 mol-% $Ph_3PAuOTf$	*p*TSA·H_2O	84%[d]
7	5 mol-% $Ph_3PAuNTf_2$	*p*TSA·H_2O	92%
8	**2 mol-% $Ph_3PAuNTf_2$**	*p*TSA·H_2O	**92%**
9	10 mol-% Tf_2NH	*p*TSA·H_2O	–%[e]
10	–	*p*TSA·H_2O	–%[e]
11	2 mol-% $Ph_3PAuNTf_2$	–	–%[f]
12	2 mol-% $Ph_3PAuOTs$	*p*TSA·H_2O	–%[f,g]

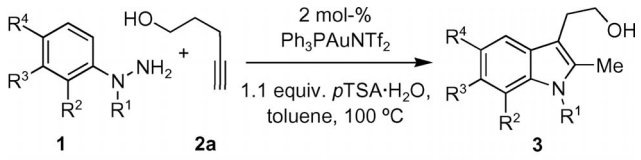
[a] A solution of the phenylhydrazine (**1a**; 0.429 mmol), 4-pentyn-1-ol (**2a**; 0.357 mmol), metal catalyst (2–10 mol-%), and *p*TSA·H_2O (0.393 mol) in toluene (2 mL) was heated at 100 °C for 2 h. [b] Isolated yield. [c] Trace amount of **3a** was detected. [d] The catalyst $Ph_3PAuOTf$ was generated by mixing equimolar amounts of Ph_3PAuCl and AgOTf. [e] The starting material **2a** was recovered in quantitative yields. [f] An inseparable mixture of unidentified products was obtained as judged by ^1H NMR spectroscopic analysis. [g] The catalyst $Ph_3PAuOTs$ was generated by mixing equimolar amounts of Ph_3PAuCl and AgOTs.

3a was not detected, which suggests that $Ph_3PAuNTf_2$ could be the active catalyst. It should be noted that the use of 1.1 equiv. of *p*TSA·H_2O is optimal; decreasing the stoichiometry resulted in a lowering of the yield of **3a**. The need for stoichiometric amounts of *p*TSA·H_2O would suggest that its role in the reaction could be to neutralize the NH_3 generated in situ, which could otherwise reduce the activity of the gold complexes.

With the optimized reaction conditions in hand, we extended the scope of the reaction to a range of arylhydrazines (Table 2). As illustrated in Table 2, 4-pentyn-1-ol (**2a**) was treated with substituted arylhydrazines **1b**–**m** to give the corresponding tryptophol derivatives **3a**–**l** in moderate to good yields. Particularly noteworthy is the fact that halo-substituents were tolerated (Table 2, entries 4, 5, and 7); therefore, the products obtained have the potential for further functionalization by conventional palladium-catalyzed cross-coupling reactions. It should also be mentioned that protecting groups, such as Cbz, allyl, and Bn, on the arylhydrazines were also tolerated (Table 2, entries 9, 10, and 11). However, the Boc group did not survive the present reaction conditions (Table 2, entry 12).

To further explore the generality and scope of this approach, a variety of alkynes were investigated (Table 3). Alkynes such as 1-hexyne (**2b**), 1-octyne (**2c**), and 4-phenyl-1-butyne (**2d**), upon reaction with **1a**, gave the expected indoles **3m**, **3n**, and **3o** in 82, 94, and 89% yields, respectively, as single regioisomers (Table 3, entries 1, 2, and 3). As can

Table 2. Scope of the reaction with respect to arylhydrazines.[a]



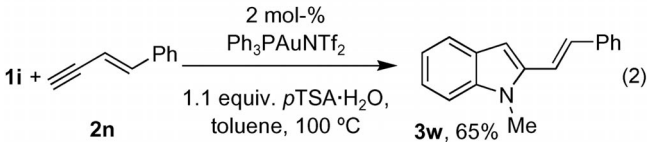
1 2a 3

Entry	1	3	Yield[b]
1	**1b** R^1 = H, R^2 = H, R^3 = H, R^4 = Me	**3b**	84%
2	**1c** R^1 = H, R^2 = H, R^3 = OMe, R^4 = H	**3c**	76%
3	**1d** R^1 = H, R^2, R^3 = -$(CH)_4$-, R^4 = H	**3d**	72%
4	**1e** R^1 = H, R^2 = H, R^3 = H, R^4 = Cl	**3e**	84%
5	**1f** R^1 = H, R^2 = H, R^3 = H, R^4 = Br	**3f**	80%
6	**1g** R^1 = H, R^2 = H, R^3 = H, R^4 = F	**3g**	82%
7	**1h** R^1 = H, R^2 = I, R^3 = H, R^4 = H	**3h**	88%
8	**1i** R^1 = Me, R^2 = H, R^3 = H, R^4 = H	**3i**	86%
9	**1j** R^1 = Cbz, R^2 = H, R^3 = H, R^4 = H	**3j**	76%
10	**1k** R^1 = allyl, R^2 = H, R^3 = H, R^4 = H	**3k**	80%
11	**1l** R^1 = Bn, R^2 = H, R^3 = H, R^4 = H	**3l**	85%
12	**1m** R^1 = Boc, R^2 = H, R^3 = H, R^4 = H	**3a** (R^1 = H)	78%

[a] A solution of the phenylhydrazine **1** (0.429 mmol), 4-pentyn-1-ol (**2a**; 0.357 mmol), $Ph_3PAuNTf_2$ (2 mol-%), and pTSA·H_2O (0.393 mmol) in toluene (2 mL) was heated at 100 °C for 2 h. [b] Isolated yield.

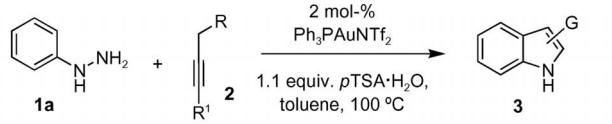
be judged from Table 3, entries 4 and 5, alkynes bearing hydroxyl and carboxylic acid groups in the tether were all tolerated. The protected tryptophol derivative **3r** was obtained by reaction of **1a** with **2g** (Table 3, entry 6). Interestingly, the reaction of phenylhydrazine (**1a**) with alkyne **2h** proceeded well, to afford **3s** in 86% yield, indicating the tolerance of the reaction towards ester groups under the present conditions (Table 3, entry 7). Even internal alkynes bearing a hydroxyl group in the tether, such as **2i** and **2j**, worked well; however, a mixture of regioisomeric indoles were obtained in these cases (Table 3, entries 8 and 9).[14] Similarly, as anticipated, the reaction of 3-pentyn-1-ol (**2k**) and 4-hexynoic acid (**2l**) with **1a** afforded **3a** and **3q** in 82 and 64% yields, respectively (Table 3, entries 10 and 11). Unfortunately, 4-octyne turned out to be inert under the present reaction conditions (Table 3, entry 12).

A successful implementation of this strategy for the synthesis of 2-vinylindoles has been demonstrated. For example, the reaction between *N*-methyl-*N*-phenylhydrazine (**1i**) and enyne **2n** under the standard reaction conditions gave the desired product **3w** in 65% yield; see Equation (2). Notably, 2-vinylindoles frequently occur as subunits in intermediates for drug and alkaloid synthesis,[15] and they have proven to be versatile dienes in Diels–Alder reactions.[16]



(2)

Table 3. Scope of the reaction with respect to alkynes.[a]



1a 2 3

Entry	2	3	Yield[b]
1	**2b** R = *n*Pr, R^1 = H	**3m**	82%
2	**2c** R = *n*Pent, R^1 = H	**3n**	94%
3	**2d** R = CH_2Ph, R^1 = H	**3o**	89%
4	**2e** R = $(CH_2)_3$OH, R^1 = H	**3p**	92%
5	**2f** R = $(CH_2)_2$COOH, R^1 = H	**3q**	88%
6	**2g** R = $(CH_2)_2$OBn, R^1 = H	**3r**	85%
7	**2h** R = $(CH_2)_2COOCH_3$, R^1 = H	**3s**	86%
8	**2i** R = CH_2OH, R^1 = C_2H_5	**3t** / **3t'**	78% / 20%
9	**2j** R = CH_2OH, R^1 = *n*Hex	**3u** / **3u'**	62% / 18%
10	**2k** R = CH_2OH, R^1 = CH_3	**3a**	82%
11	**2l** R = CH_2COOH, R^1 = CH_3	**3q**	64%
12	**2m** R = *n*Et, R^1 = *n*Pr	----- **3v**	–%[c]

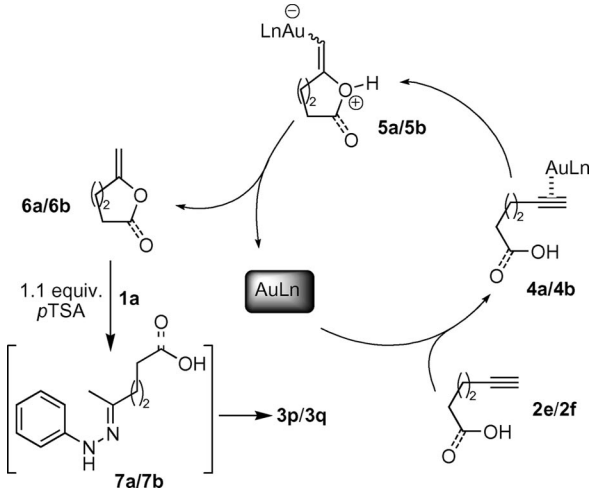
[a] A solution of the phenylhydrazine (**1a**; 0.429 mmol), alkyne **2** (0.357 mmol), $Ph_3PAuNTf_2$ (2 mol-%), and pTSA·H_2O (0.393 mmol) in toluene (2 mL) was heated at 100 °C for 2 h. [b] Isolated yield. [c] 4-Octyne (**2m**) was recovered in quantitative yields.

Mechanistic Studies

From Tables 2 and 3, it can be seen that the reaction works very well for terminal alkynes with or without OH/COOH groups in the tether. However, internal alkynes that lack such groups in the tether did not react with **1a** under the standard conditions (Table 3, entry 12). The presence of OH/COOH groups in the tether is necessary for these reactions to occur (Table 3, entries 8–11). Based on these results, we propose two mechanistically different sets of mechanisms: (1) In the case of alkynes in which the OH/COOH group is present in the tether, a hydroalkoxylation/hydrocarboxylation mechanism can operate to generate exocyclic enol ethers/lactones, which would react with hydrazines to give indoles. (2) In the case of alkynes that lack OH/COOH groups, a hydration mechanism operates to form ketones that condense with arylhydrazines to give indoles through Fisher indolization.

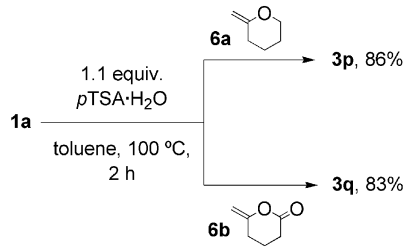
Mechanism for Alkynes Bearing OH/COOH Groups in the Tether

In a mechanism involving intramolecular cyclization of alkynols and alkynoic acids leading to the formation of exocyclic enol ether/lactones (Scheme 1), the first step would be the complexation of the Au^I catalyst to the alkyne function in **2e/2f**, which leads to the formation of an intermediate **4a/4b**. The cyclization may then occur directly by attack of the proximal hydroxy[17]/carboxy group[18] to form the vinylgold intermediate **5a/5b**.[19] The next step would involve proto-demetalation to generate the exocyclic enol ether/lactones **6a/6b** with the release of catalyst. Once **6a/6b** is formed, the next step would be the reaction with phenylhydrazine (**1a**) to form hydrazone **7a/7b**, which would undergo Fischer indolization to form products **3p/3q**. Because of the intermediacy of the cyclic enol ether/lactone,[20] the overall process can be termed as being a OH/COOH assisted[11c,11f,11g] formal hydrohydrazination–Fischer indolization tandem reaction.



Scheme 1. Proposed mechanism for alkynes having a OH/COOH group in the tether.

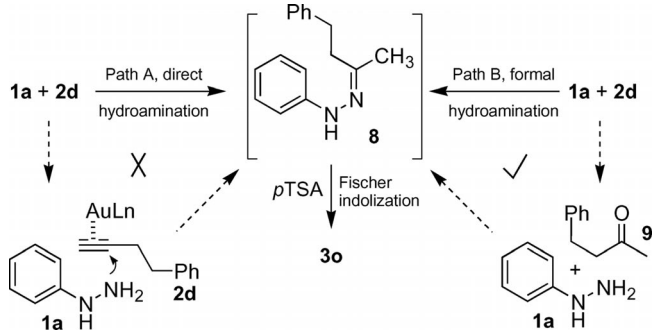
We then wanted to establish unequivocally the intermediacy of the enol ethers and enol lactones. Accordingly, tetrahydro-2-methylene-2*H*-pyran (**6a**)[21] and tetrahydro-6-methylenepyran-2-one (**6b**)[22] were prepared by known procedures and treated with **1a** under the conditions described above (Scheme 2). Under these conditions, **3p** and **3q** were obtained in 86 and 83% yields, respectively. However, it is also possible that, in the presence of hydrated *p*TSA, **6a** and **6b** may open up to form the corresponding ketones, and it may be these ring-opened species that are the actual reaction partners.[23] It was also found that the reaction proceeded well under anhydrous conditions; see Equations (5) and (6) below.



Scheme 2. Reaction of **1a** with enol ether **6a** and enol lactone **6b**.

Mechanism for Alkynes Lacking OH/COOH Groups in the Tether

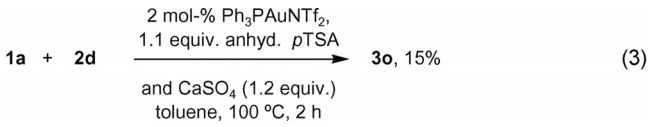
In a plausible mechanism for alkynes that do not bear OH/COOH groups in the tether (Scheme 3), the first step would be the generation of arylhydrazone **8** from **1a** and **2d**. The arylhydrazone **8**, thus formed, can be converted into the final product **3o** through a *p*TSA·H_2O assisted Fischer indolization process. There are two ways to arrive at **8**. The first would be direct hydroamination involving addition of N–H across the alkyne (Path A), whereas the second involves the Au^I catalyzed hydration of alkyne **2d**[24] to generate ketone **9**, which would then condense with **1a** (Path B). The latter process can be termed a formal hydroamination because overall addition of the hydrazine takes place on the alkynes.



Scheme 3. Proposed mechanism for alkynes without a OH/COOH group in the tether.

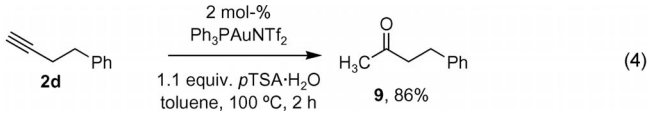
To gain further insight into the mechanism, and especially to establish whether direct or formal hydroamination takes place, a number of control experiments were performed. When **1a** was treated with **2d** in the presence of

2 mol-% $Ph_3PAuNTf_2$ and 1.1 equiv. anhydrous *p*TSA[25] in toluene (freshly distilled from sodium) using $CaSO_4$ as desiccant at 100 °C for 2 h in a glove-box, the desired product **3o** was obtained in 15% yield; see Equation (3). Because the yield dropped significantly in the presence of desiccant, we assume Path B (formal hydroamination) is operating.



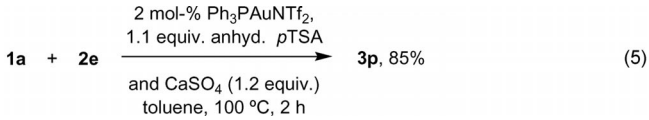
(3)

To prove the existence of the alkyne hydration product (Scheme 3, Path B), a further control experiment was conducted. Accordingly, alkyne **2d** was subjected to the standard reaction conditions, in the absence of **1a**; see Equation (4). In this case, ketone **9** was obtained in 86% yield.



(4)

Interestingly, when **1a** was independently treated with **2e** and **2f**, in the presence of 2 mol-% $Ph_3PAuNTf_2$ and 1.1 equiv. anhydrous *p*TSA in anhydrous toluene using $CaSO_4$ as desiccant, at 100 °C for 2 h in a glove-box, the desired products **3p** and **3q** were obtained in 85 and 88% yields, respectively; see Equations (5) and (6). This result proves that water is not necessary for the reaction of alkynes bearing OH/COOH groups in the tether and provides further support for the mechanism depicted in Scheme 2.



(5)

(6)

Conclusions

A binary catalytic system involving the combination of $Ph_3PAuNTf_2$ and *p*TSA·H_2O, has been successfully developed for the synthesis of 2,3-disubstituted indoles from arylhydrazines and alkynes. The results indicate that $Ph_3PAuNTf_2$ catalyst is compatible with *p*TSA·H_2O at high temperature. A low catalyst loading of $Ph_3PAuNTf_2$, its tolerance of moisture, and the short reaction time makes this method convenient. More importantly, an interesting mechanistic dichotomy was observed that depended on the type of alkyne used, and which would enable this formal hydroamination chemistry to be applied to the synthesis of other related heterocycles.

Experimental Section

Preparation of 3a as a Representative Example: To a toluene (2 mL) solution of **2a** (30 mg, 0.357 mmol) and **1a** (46 mg, 0.429 mmol) in a 2.5 mL screw-cap vial, was added *p*TSA·H_2O (78 mg, 0.393 mmol) and $Ph_3PAuNTf_2$ (11 mg, 2 mol-%) under a nitrogen atmosphere. The mixture was stirred at 100 °C for 2 h, then cooled and filtered through a pad of silica gel, eluting with ethyl acetate. The solvent was removed under reduced pressure and the residue was purified by flash silica gel column chromatography (ethyl acetate/hexane, 3:7) to obtain **3a** as a pure compound.

2-(2-Methyl-1*H*-3-indolyl)-1-ethanol (3a):[26] Yield 57 mg (92%); viscous oil; R_f = 0.50 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.75 (br. s, 1 H), 7.43 (d, J = 6.9 Hz, 1 H), 7.18 (d, J = 8.1 Hz, 1 H), 7.08–6.98 (m, 2 H), 3.79 (t, J = 6.2 Hz, 2 H), 2.93 (t, J = 6.2 Hz, 2 H), 2.39 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.1, 132.3, 128.4, 120.9, 119.1, 117.7, 110.1, 107.2, 62.5, 27.4, 11.4 ppm. IR (film): $\tilde{\nu}_{max}$ = 3400, 3055, 2923, 1621, 1461, 1433, 1343, 1300, 1195, 1138, 1042, 1009, 743, 589, 510, 433 cm^{-1}. MS (EI): m/z = 175 [M$^{+\cdot}$]. HRMS: calcd. for $C_{11}H_{14}NO$ [M$^+$ + H] 176.1075; found 176.1069.

2-(2,5-Dimethyl-1*H*-3-indolyl)-1-ethanol (3b): Yield 56 mg (84%); pale-brown solid; m.p. 114–116 °C; R_f = 0.46 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.66 (br. s, 1 H), 7.21 (s, 1 H), 7.05 (d, J = 8.3 Hz, 1 H), 6.87 (d, J = 8.3 Hz, 1 H), 3.78 (t, J = 6.0 Hz, 2 H), 2.89 (t, J = 6.0 Hz, 2 H), 2.42 (s, 3 H), 2.36 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 136.5, 133.6, 132.6, 128.9, 122.6, 117.7, 109.9, 106.9, 62.8, 27.7, 21.5, 11.7 ppm. IR (KBr): $\tilde{\nu}_{max}$ = 3391, 3251, 2922, 2858, 1587, 1451, 1433, 1355, 1305, 1044, 872, 794, 641, 596, 509, 431 cm^{-1}. MS (ESI): m/z = 190 [M$^+$ + H]. HRMS: calcd. for $C_{12}H_{16}NO$ [M$^+$ + H] 190.1232; found 190.1228.

2-(6-Methoxy-2-methyl-1*H*-3-indolyl)-1-ethanol (3c): Yield 56 mg (76%); viscous oil; R_f = 0.38 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.75 (br. s, 1 H), 7.27 (d, J = 9.0 Hz, 1 H), 6.65–6.63 (m, 2 H), 3.78 (s, 3 H), 3.73 (t, J = 6.0 Hz, 2 H), 2.86 (t, J = 6.0 Hz, 2 H), 2.31 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.2, 133.6, 124.7, 120.9, 118.5, 118.3, 111.4, 108.6, 62.8, 55.8, 27.7, 8.7 ppm. IR (film): $\tilde{\nu}_{max}$ = 3386, 3055, 2924, 2855, 1718, 1623, 1462, 1337, 1242, 1199, 1159, 1041, 814, 647, 556, 518 cm^{-1}. MS (ESI): m/z = 206 [M$^+$ + H]. HRMS: calcd. for $C_{12}H_{16}NO_2$ [M$^+$ + H] 206.1181; found 206.1183.

2-(2-Methyl-1*H*-benzo[*f*]indol-3-yl)-1-ethanol (3d): Yield 58 mg (72%); viscous oil; R_f = 0.44 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.72 (br. s, 1 H), 7.89 (m, 2 H), 7.62 (d, J = 8.3 Hz, 1 H), 7.46 (m, 2 H), 7.36 (t, J = 6.8 Hz, 1 H), 3.86 (t, J = 6.8 Hz, 2 H), 3.01 (t, J = 6.8 Hz, 2 H), 2.46 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 130.5, 129.9, 129.5, 128.9, 125.3, 124.6, 123.4, 121.3, 120.1, 119.2, 118.6, 118.5, 63.1, 27.8, 11.8 ppm. IR (film): $\tilde{\nu}_{max}$ = 3416, 3052, 2926, 1704, 1655, 1551, 1429, 1382, 1296, 1258, 1214, 1160, 1112, 1037, 863, 805, 748, 563 cm^{-1}. MS (ESI): m/z = 226 [M$^+$ + H]. HRMS: calcd. for $C_{15}H_{16}NO$ [M$^+$ + H] 226.1232; found 226.1228.

2-(5-Chloro-2-methyl-1*H*-3-indolyl)-1-ethanol (3e): Yield 63 mg (84%); viscous oil; R_f = 0.47 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.83 (br. s, 1 H), 7.40 (d, J = 1.5 Hz, 1 H),

7.12–7.09 (m, 1 H), 7.02 (t, J = 6.0 Hz, 1 H), 3.78 (t, J = 6.0 Hz, 2 H), 2.88 (t, J = 6.0 Hz, 2 H), 2.39 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.0, 133.9, 128.6, 121.3, 119.8, 117.5, 111.2, 107.6, 62.6, 27.6, 11.8 ppm. IR (film): $\tilde{\nu}_{max}$ = 3410, 2932, 1726, 1623, 1573, 1482, 1452, 1364, 1324, 1230, 1169, 1124, 1056, 743, 589, 520, 432 cm^{-1}. MS (ESI): m/z = 210 [M$^+$ + H]. HRMS: calcd. for $C_{11}H_{13}ClNO$ [M$^+$ + H] 210.0686; found 210.0682.

2-(5-Bromomethyl-1*H*-3-indolyl)-1-ethanol (3f): Yield 72 mg (80%); viscous oil; R_f = 0.71 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.80 (br. s, 1 H), 7.59 (d, J = 8.3 Hz, 1 H), 7.15 (m, 1 H), 7.05 (d, J = 8.3 Hz, 1 H), 4.17 (t, J = 6.8 Hz, 2 H), 2.94 (t, J = 6.8 Hz, 2 H), 2.39 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 133.7, 130.7, 130.2, 123.7, 120.5, 116.5, 112.4, 111.6, 64.4, 23.6, 11.6 ppm. IR (film): $\tilde{\nu}_{max}$ = 3402, 3058, 2928, 1635, 1582, 1482, 1450, 1379, 1221, 1168, 1102, 1023, 748, 600, 432 cm^{-1}. MS (ESI): m/z = 254 [M$^+$ + H]. HRMS: calcd. for $C_{11}H_{13}BrNO$ [M$^+$ + H] 254.0181; found 254.0176.

2-(5-Fluoromethyl-1*H*-3-indolyl)-1-ethanol (3g): Yield 56 mg (82%); viscous oil; R_f = 0.48 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.90 (br. s, 1 H), 7.09 (d, J = 3.7 Hz, 1 H), 7.06 (d, J = 3.7 Hz, 1 H), 6.78 (t, J = 6.8 Hz, 1 H), 3.77 (t, J = 6.0 Hz, 2 H), 2.87 (t, J = 6.0 Hz, 2 H), 2.36 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 160.1, 159.4, 132.6, 131.7, 128.5, 122.0, 115.7, 112.9, 110.7, 108.9, 103.2, 102.9, 62.7, 27.7, 11.8 ppm. IR (film): $\tilde{\nu}_{max}$ = 3409, 3055, 2924, 1706, 1655, 1584, 1485, 1451, 1387, 1304, 1231, 1178, 1104, 1042, 958, 848, 795, 602, 434 cm^{-1}. MS (ESI): m/z = 194 [M$^+$ + H]. HRMS: calcd. for $C_{11}H_{13}FNO$ [M$^+$ + H] 194.0981; found 194.0978.

2-(7-Iodo-2-methyl-1*H*-3-indolyl)-1-ethanol (3h): Yield 94 mg (88%); viscous oil; R_f = 0.55 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.84 (br. s, 1 H), 7.41 (m, 2 H), 6.80 (t, J = 7.5 Hz, 1 H), 3.79 (t, J = 6.0 Hz, 2 H), 2.89 (t, J = 6.0 Hz, 2 H), 2.45 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 138.5, 132.9, 131.2, 129.6, 121.0, 118.0, 109.3, 105.9, 62.7, 27.9, 11.8 ppm. IR (film): $\tilde{\nu}_{max}$ = 3402, 2924, 1624, 1463, 1345, 1323, 1196, 1140, 1048, 1008, 743, 586, 512, 430 cm^{-1}. MS (ESI): m/z = 302 [M$^+$ + H]. HRMS: calcd. for $C_{11}H_{13}INO$ [M$^+$ + H] 302.0042; found 302.0038.

2-(1,2-Dimethyl-1*H*-3-indolyl)-1-ethanol (3i):[13] Yield 58 mg (86%); viscous oil; R_f = 0.70 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): 7.44 (d, J = 7.5 Hz, 1 H), 7.16 (d, J = 7.5 Hz, 1 H), 7.08 (d, J = 8.3 Hz, 1 H), 7.00 (d, J = 8.3 Hz, 1 H), 3.75 (t, J = 6.0 Hz, 2 H), 3.65 (s, 3 H), 2.94 (t, J = 6.0 Hz, 2 H), 2.37 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 136.6, 134.2, 127.7, 120.7, 118.9, 117.8, 108.6, 106.6, 62.9, 29.5, 27.9, 10.3 ppm. IR (film): $\tilde{\nu}_{max}$ = 3396, 3048, 2924, 1615, 1470, 1433, 1367, 1329, 1243, 1185, 1039, 883, 737, 558 cm^{-1}. MS (ESI): m/z = 190 [M$^+$ + H]. HRMS: calcd. for $C_{12}H_{16}NO$ [M$^+$ + H] 190.1231; found 190.1236.

Benzyl 3-(2-Hydroxyethyl)-2-methyl-1*H*-1-indolecarboxylate (3j): Yield 84 mg (76%); viscous oil; R_f = 0.68 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.48 (d, J = 1.5 Hz, 1 H), 7.46 (d, J = 1.5 Hz, 1 H), 7.42–7.34 (m, 5 H), 7.18–7.15 (m, 2 H), 5.44 (s, 2 H), 3.78 (t, J = 6.0 Hz, 2 H), 2.91 (t, J = 6.0 Hz, 2 H), 2.57 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 157.1, 132.4, 130.4, 129.1, 128.8, 128.7, 128.6, 128.4, 123.8, 122.8, 117.8, 115.7, 68.6, 62.2, 27.5, 11.2 ppm. IR (film): $\tilde{\nu}_{max}$ = 3386, 3045, 2924, 1618, 1460, 1430, 1342, 1192, 1130, 1040, 1007, 740, 586, 508, 430 cm^{-1}. MS (ESI): m/z = 310 [M$^+$ + H]. HRMS: calcd. for $C_{19}H_{20}NO_3$ [M$^+$ + H] 310.1443; found 310.1438.

2-(1-Allyl-2-methyl-1*H*-3-indolyl)-1-ethanol (3k): Yield 61 mg (80%); viscous oil; R_f = 0.65 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.45 (d, J = 7.5 Hz, 1 H), 7.13 (d, J = 7.5 Hz, 1 H), 7.07 (d, J = 6.8 Hz, 1 H), 7.00 (d, J = 6.8 Hz, 1 H), 5.95–5.82 (m, 1 H), 5.08 (d, J = 10.5 Hz, 1 H), 4.78 (d, J = 18.1 Hz, 1 H), 4.65–4.62 (m, 2 H), 3.75 (t, J = 6.0 Hz, 2 H), 2.94 (t, J = 6.0 Hz, 2 H), 2.33 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 136.2, 133.9, 133.5, 127.9, 120.9, 119.1, 117.9, 116.2, 109.0, 107.2, 62.9, 45.4, 28.0, 10.1 ppm. IR (film): $\tilde{\nu}_{max}$ = 3392, 3055, 2922, 1620, 1462, 1430, 1340, 1302, 1192, 1136, 1040, 1008, 740, 586, 508, 432 cm^{-1}. MS (ESI): m/z = 216 [M$^+$ + H]. HRMS: calcd. for $C_{14}H_{18}NO$ [M$^+$ + H] 216.1388; found 216.1380.

2-(1-Benzyl-2methyl-1*H*-3-indolyl)-1-ethanol (3l):[27] Yield 80 mg (85%); viscous oil; R_f = 0.62 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.51–7.48 (m, 1 H), 7.26–7.13 (m, 4 H), 7.00–7.09 (m, 2 H), 6.90 (d, J = 6.8 Hz, 2 H), 5.28 (s, 2 H), 3.80 (t, J = 6.0 Hz, 2 H), 2.98 (t, J = 6.0 Hz, 2 H), 2.31 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 137.8, 136.6, 134.0, 128.7, 127.2, 125.9, 121.0, 119.2, 117.9, 109.0, 107.4, 62.9, 46.5, 28.0, 10.3 ppm. IR (film): $\tilde{\nu}_{max}$ = 3408, 3058, 2926, 1704, 1628, 1575, 1480, 1448, 1376, 1218, 1164, 1100, 1020, 746, 582, 430 cm^{-1}. MS (ESI): m/z = 266 [M$^+$ + H]. HRMS: calcd. for $C_{18}H_{20}NO$ [M$^+$ + H] 266.1545; found 266.1540.

2-Methyl-3-propyl-1*H*-indole (3m):[28] Yield 51 mg (82%); viscous oil; R_f = 0.80 (hexane/EtOAc, 90:10). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.57 (br. s, 1 H), 7.42 (d, J = 6.8 Hz, 1 H), 7.13 (d, J = 6.8 Hz, 1 H), 7.04–6.95 (m, 2 H), 2.63 (t, J = 7.5 Hz, 2 H), 2.32 (s, 3 H), 1.69–1.57 (m, 2 H), 0.93 (t, J = 7.5 Hz, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.0, 129.4, 128.5, 120.6, 118.7, 117.9, 109.7, 109.2, 31.6, 23.9, 13.9, 11.5 ppm. IR (film): $\tilde{\nu}_{max}$ = 3476, 3054, 2957, 2925, 2864, 1649, 1458, 1300, 1223, 1153, 1012, 741, 660, 587 cm^{-1}. MS (ESI): m/z = 174 [M$^+$ + H]. HRMS: calcd. for $C_{12}H_{16}N$ [M$^+$ + H] 174.1283; found 174.1288.

2-Methyl-3-pentyl-1*H*-indole (3n): Yield 67 mg (94%); viscous oil; R_f = 0.82 (hexane/EtOAc, 90:10). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.58 (br. s, 1 H), 7.41 (d, J = 6.8 Hz, 1 H), 7.13 (d, J = 6.8 Hz, 1 H), 7.03–6.95 (m, 2 H), 2.64 (t, J = 6.8 Hz, 2 H), 2.32 (s, 3 H), 1.60 (pseudo-t, J = 6.8, 7.6 Hz, 2 H), 1.33–1.27 (m, 4 H), 0.88 (t, J = 6.8 Hz, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.3, 129.7, 128.7, 120.8, 119.0, 118.2, 110.0, 109.5, 31.8, 30.5, 24.2, 22.7, 14.2, 11.7 ppm. IR (film): $\tilde{\nu}_{max}$ = 3473, 3042, 2932, 2922, 2856, 1638, 1446, 1320, 1234, 1158, 1029, 734, 623, 524 cm^{-1}. MS (ESI): m/z = 202 [M$^+$ + H]. HRMS: calcd. for $C_{14}H_{20}N$ [M$^+$ + H] 202.1596; found 202.1590.

3-Benzyl-2-methyl-1*H*-indole (3o):[29] Yield 70 mg (89%); viscous oil; R_f = 0.76 (hexane/EtOAc, 90:10). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.70 (br. s, 1 H), 7.29–7.32 (m, 1 H), 7.19–7.13 (m, 5 H), 7.11–7.08 (m, 1 H), 7.05–6.92 (m, 2 H), 4.03 (s, 2 H), 2.37 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 141.7, 131.7, 130.4, 128.6, 128.3, 126.8, 125.7, 120.9, 119.2, 118.4, 112.4, 110.2, 45.2, 11.8 ppm. IR (film): $\tilde{\nu}_{max}$ = 3403, 3052, 2952, 2864, 1649, 1457, 1432, 1322, 1190, 1132, 1041, 1002, 740, 586, 506, 430 cm^{-1}. MS (ESI): m/z = 222 [M$^+$ + H]. HRMS: calcd. for $C_{16}H_{16}N$ [M$^+$ + H] 222.1283; found 222.1278.

3-(2-Methyl-1*H*-3-indolyl)-1-propanol (3p):[30] Yield 62 mg (92%); viscous oil; R_f = 0.52 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.65 (br. s, 1 H), 7.42 (d, J = 8.3 Hz, 1 H), 7.14 (d, J = 8.3 Hz, 1 H), 7.04–6.98 (m, 2 H), 3.59 (t, J = 6.2 Hz, 2 H), 2.75 (d, J = 7.3 Hz, 2 H), 2.33 (s, 3 H), 1.85 (pent, J = 6.2, 7.3 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.2, 130.9, 128.5, 120.7, 118.9, 117.8, 111.0, 110.2, 62.4, 33.2, 20.1, 11.4 ppm. IR (film): $\tilde{\nu}_{max}$ = 3385, 3045, 2920, 1611, 1452, 1423, 1323, 1305, 1185, 1128, 1022, 1002, 728, 569, 502, 428 cm^{-1}. MS (ESI): m/z = 190 [M$^+$ + H]. HRMS: calcd. for $C_{12}H_{16}NO$ [M$^+$ + H] 190.1232; found 190.1228.

3-(2-Methyl-1*H*-3-indolyl)propanoic Acid (3q):[31] Yield 64 mg (88%); pale-yellow solid; m.p. 132–134 °C; R_f = 0.29 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.60 (br. s, 1 H), 7.43 (d, J = 6.8 Hz, 1 H), 7.18 (d, J = 6.8 Hz, 1 H), 7.07–6.98 (m, 2 H), 3.01 (t, J = 7.6 Hz, 2 H), 2.65 (t, J = 7.6 Hz, 2 H), 2.39 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 179.0, 135.3, 131.4, 128.2, 121.0, 119.2, 117.8, 110.3, 109.8, 34.9, 19.6, 11.6 ppm. IR (KBr): $\tilde{\nu}_{max}$ = 3399, 3053, 2921, 1669, 1591, 1489, 1430, 1377, 1334, 1305, 1243, 1167, 1106, 1074, 1020, 844, 757, 696, 634, 565, 508, 468, 402 cm^{-1}. MS (ESI): m/z = 204 [M^+ + H]. HRMS: calcd. for $C_{12}H_{14}NO_2$ [M^+ + H] 204.1025; found 204.1022.

3-[2-(Benzyloxy)ethyl]-2-methyl-1*H*-indole (3r): Yield 80 mg (85%); viscous oil; R_f = 0.77 (hexane/EtOAc, 90:10). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.68 (br. s, 1 H), 7.55–7.44 (m, 5 H), 7.41 (d, J = 7.3 Hz, 1 H), 7.16 (d, J = 8.1 Hz, 1 H), 7.04–6.96 (m, 2 H), 4.49 (s, 2 H), 3.62 (t, J = 7.3 Hz, 2 H), 2.99 (t, J = 7.3 Hz, 2 H), 2.37 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 134.2, 133.0, 132.8, 131.3, 129.5, 129.1, 128.8, 128.4, 128.2, 127.7, 127.6, 122.6, 72.9, 69.3, 23.8, 13.1 ppm. IR (film): $\tilde{\nu}_{max}$ = 3408, 3045, 2920, 1620, 1452, 1432, 1336, 1190, 1048, 1005, 728, 506, 423 cm^{-1}. MS (ESI): m/z (%) = 266 [M^+ + H]. HRMS: calcd. for $C_{18}H_{20}NO$ [M^+ + H] 266.1545; found 266.1542.

Methyl 3-(2-Methyl-1*H*-3-indolyl)propanoate (3s):[32] Yield 67 mg (86%); viscous oil; R_f = 0.78 (hexane/EtOAc, 90:10). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.75 (br. s, 1 H), 7.42 (d, J = 6.9 Hz, 1 H), 7.16 (d, J = 6.9 Hz, 1 H), 7.06–6.99 (m, 2 H), 3.63 (s, 3 H), 3.01 (t, J = 7.7 Hz, 2 H), 2.60 (t, J = 7.7 Hz, 2 H), 2.38 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 173.9, 135.1, 131.2, 128.1, 120.9, 119.1, 117.7, 110.2, 110.0, 51.5, 34.9, 19.7, 11.4 ppm. IR (film): $\tilde{\nu}_{max}$ = 3408, 3028, 2926, 2612, 1680, 1460, 1432, 1302, 1212, 1008, 920, 750, 680, 645, 584, 486 cm^{-1}. MS (ESI): m/z = 218 [M^+ + H]. HRMS: calcd. for $C_{13}H_{16}NO_2$ [M^+ + H] 218.1181; found, 218.1174.

3-(3-Methyl-1*H*-2-indolyl)-1-propanol (3t):[33] Yield 53 mg (78%); viscous oil; R_f = 0.42 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.15 (br. s, 1 H), 7.39 (d, J = 6.8 Hz, 1 H), 7.11 (d, J = 6.8 Hz, 1 H), 7.04–6.97 (m, 2 H), 3.52 (t, J = 6.0 Hz, 2 H), 2.68 (t, J = 6.8 Hz, 2 H), 2.17 (s, 3 H), 1.74 (pt, J = 6.0, 6.8 Hz, 2 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.1, 134.4, 129.2, 120.8, 118.8, 117.9, 110.2, 106.7, 61.8, 31.9, 22.3, 8.4 ppm. IR (film): $\tilde{\nu}_{max}$ = 3402, 3055, 2925, 2860, 1707, 1621, 1462, 1382, 1330, 1240, 1033, 1009, 921, 744, 477 cm^{-1}. MS (ESI): m/z = 190 [M^+ + H]. HRMS: calcd. for $C_{12}H_{16}NO$ [M^+ + H] 190.1232; found 190.1228.

2-(2-Ethyl-1*H*-3-indolyl)-1-ethanol (3t′):[34] Yield 13 mg (20%); viscous oil; R_f = 0.48 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.86 (br. s, 1 H), 7.45 (d, J = 6.8 Hz, 1 H), 7.20 (d, J = 7.5 Hz, 1 H), 7.08–6.98 (m, 2 H), 3.79 (t, J = 6.0 Hz, 2 H), 2.94 (t, J = 6.8 Hz, 2 H), 2.77 (q, J = 7.5 Hz, 2 H), 1.27 (t, J = 7.5 Hz, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 138.3, 135.3, 128.6, 121.2, 119.3, 118.1, 110.4, 106.5, 62.8, 27.6, 19.3, 14.4 ppm. IR (film): $\tilde{\nu}_{max}$ = 3408, 3045, 2923, 2862, 1705, 1620, 1460, 1382, 1330, 1244, 1033, 920, 744, 457 cm^{-1}. MS (ESI): m/z = 190 [M^+ + H]. HRMS: calcd. for $C_{12}H_{16}NO$ [M^+ + H] 190.1232; found 190.1230.

3-(3-Pentyl-1*H*-2-indolyl)-1-propanol (3u): Yield 54 mg (62%); viscous oil; R_f = 0.40 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 8.12 (br. s, 1 H), 7.42 (d, J = 6.8 Hz, 1 H), 7.17 (d, J = 6.8 Hz, 1 H), 7.04–6.95 (m, 2 H), 3.69 (t, J = 6.0 Hz, 2 H), 2.84 (t, J = 6.8 Hz, 2 H), 2.65 (t, J = 6.8 Hz, 2 H), 1.88 (pseudo-t, J = 6.0, 6.8 Hz, 2 H), 1.60 (t, J = 6.0 Hz, 2 H), 1.36–1.30 (m, 4 H), 0.89 (t, J = 6.0 Hz, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.3, 134.3, 121.8, 120.8, 118.8, 118.3, 112.4, 110.3, 62.0, 32.2, 31.9, 30.8, 24.1, 22.6, 22.4, 14.1 ppm. IR (film): $\tilde{\nu}_{max}$ = 3402, 3055, 2925, 2860, 1707, 1621, 1462, 1382, 1330, 1240, 1033, 1009, 921, 744, 477 cm^{-1}. MS (ESI): m/z = 246 [M^+ + H]. HRMS: calcd. for $C_{16}H_{24}NO$ [M^+ + H] 246.1858; found 246.1852.

2-(2-Hexyl-1*H*-3-indolyl)-1-ethanol (3u′): Yield 16 mg (18%); viscous oil; R_f = 0.44 (hexane/EtOAc, 60:40). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.97 (br. s, 1 H), 7.46 (d, J = 7.5 Hz, 1 H), 7.20 (d, J = 6.8 Hz, 1 H), 7.09–6.98 (m, 2 H), 3.80 (t, J = 6.0 Hz, 2 H), 2.94 (t, J = 6.8 Hz, 2 H), 2.74 (t, J = 7.5 Hz, 2 H), 1.65 (pseudo-t, J = 8.3, 7.5 Hz, 2 H), 1.37–1.20 (m, 6 H), 0.89 (t, J = 8.3 Hz, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.7, 134.7, 122.6, 121.2, 119.2, 118.8, 112.8, 110.7, 62.5, 32.6, 32.4, 31.2, 24.6, 23.0, 22.8, 14.5 ppm. IR (film): $\tilde{\nu}_{max}$ = 3412, 3054, 2928, 2862, 1705, 1620, 1466, 1380, 1338, 1242, 1035, 1012, 924, 746, 478 cm^{-1}. MS (ESI): m/z = 246 [M^+ + H]. HRMS: calcd. for $C_{16}H_{24}NO$ [M^+ + H] 246.1858; found 246.1850.

1-Methyl-2-[(*E*)-2-phenyl-1-ethenyl]-1*H*-indole (3w):[35] Yield 54 mg (64%); pale-yellow solid; m.p. 118–120 °C; R_f = 0.78 (hexane/EtOAc, 90:10). ^{1}H NMR (300 MHz, $CDCl_3$): δ = 7.66 (d, J = 1.5 Hz, 1 H), 7.63 (s, 1 H), 7.45 (s, 1 H), 7.34–7.32 (m, 4 H), 7.29 (d, J = 1.5 Hz, 1 H), 7.26 (s, 1 H), 7.24 (s, 1 H), 7.21–7.15 (m, 1 H), 6.85–6.90 (m, 1 H), 3.44 (s, 3 H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$): δ = 147.8, 136.7, 131.8, 128.9, 128.5, 128.1, 127.6, 126.0, 120.5, 118.7, 115.2, 113.1, 108.4, 32.9 ppm. IR (KBr): $\tilde{\nu}_{max}$ = 3055, 2922, 1620, 1462, 1434, 1342, 1302, 1194, 1136, 1040, 1008, 742, 588 cm^{-1}. MS (ESI): m/z = 234 [M^+ + H]. HRMS: calcd. for $C_{17}H_{16}N$ [M^+ + H] 234.1283; found 234.1278.

Representative Procedure for the Synthesis of Indoles from the Enol Ether and Enol Lactone: (Scheme 1) To a solution of **6a/6b** (0.357 mmol) and **1a** (0.429 mmol) in toluene (2 mL), in a 2.5 mL screw-cap vial, was added *p*TSA·H_2O (0.393 mmol) under a nitrogen atmosphere. The mixture was stirred at 100 °C for 2 h, then cooled and filtered through a pad of silica gel eluting with ethyl acetate. The solvent was removed under reduced pressure and the residue was purified by flash silica gel column chromatography (ethyl acetate/hexane, 3:7) to obtain **3p/3q** as a pure compound.

Supporting Information (see also the footnote on the first page of this article): Synthesis of starting materials, experimental procedures, characterization data, ^{1}H and ^{13}C NMR spectra.

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