Synthesis of Annelated Substituted Bipyridines and Terpyridines by Cobalt(I)-Catalyzed [2 + 2 + 2] Cycloaddition†

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Introduction

The principles of supramolecular chemistry[1] provide guidelines for the construction of relatively complex molecular systems from simple components. Over the last decade there has been a considerable amount of work on metal-ion-induced self assembly of oligopyridine ligands to form polymetallic double-stranded helical and nonhelical complexes of predetermined length and geometry.[2] In these systems the metal centers are organized in a well-defined array in accordance with the well-established coordination properties of ligands such as 2,2′-bipyridine (bipy) and 2,2′:6′,2″-terpyridine (terpy).[3] These polymetallic complexes are of particular interest for the study of intramolecular electron transfer processes[4] and, ultimately, for the construction of molecular electronic and photonic devices.[5]

The majority of the strategies used to synthesize functionalized oligopyridines are based on Pd- or Ni-catalyzed heteroaryl C−C coupling reactions[6] or on the Kröhnke−Potts[7] or Friedländer[8] methods. Although these procedures can lead to either symmetrically or unsymmetrically substituted oligopyridines, most of them do not allow an easy incorporation of substituents in positions 3 and 3″ (oligopyridine numbering), and no 3,3″-substituted oligopyridines have hitherto been reported. We now describe a general procedure for the synthesis of annelated 3- and 3,3″-substituted bipyridines and terpyridines, respectively (Schemes 1 and 2), which is based on the well-known ability of Co(I) complexes to catalyze the formation of pyridine nuclei by means of [2 + 2 + 2] cycloaddition of alkynes and nitriles.[9]

Results and Discussion

We began our synthetic method with a detailed investigation of the $CpCo(CO)_2$-catalyzed cocyclization of 5-hexynenitrile (**1**) and unsubstituted 2-ethynylpyridine (**3a**).[10] Irradiation of both components and the catalyst under slow addition conditions (method A) or irradiation of the whole mixture (method B) afforded 2,2′-bipyridine **4a** and its isomer 3,2′-bipyridine **5a** in poor yields (11% and 4%, respectively). The use of 6-heptynenitrile (**2**)[9] as cocyclization partner did not improve the yield, giving 9% of 2,2′-bipyridine **6a** and 3,2′-bipyridine **7a**, respectively. Suspecting that these poor results were probably due to side reactions of the terminal alkyne,[11,12] we then tried cycloaddition between 2-[(trimethylsilyl)ethynyl]-pyridine (**3b**)[10a] and **1**, which afforded mixtures of 3-(trimethylsilyl)-2,2′-bipyridine **4b** and 3,2′-bipyridine **5a** (**5b** was observed in the crude reaction mixtures but underwent protodesilylation to **5a** during column chromatography on silica gel).[9b,13] The yield of this reaction was much better than with **3a**, although it was sensitive to various factors such as irradiation time and the proportions of starting materials and catalyst (Table 1); yields of 60−75% were achieved when the amount of "free" catalyst used was enough to ensure its presence throughout the course of the reaction. A full consumption of starting materials was observed upon slow addition of the catalyst (method C).

Similar or even slightly better results were obtained for cocyclization of **2** with **3b**, which afforded a 76% yield of 3-(trimethylsilyl)-2,2′-bipyridine **6b** and 3,2′-bipyridine **7a** in 1:1.5 ratio.

Unfortunately, the cocyclization between alkynenitriles **1** and **2** with **3b** shows poor regioselectivity. This is probably due to competition between electronic and steric factors during coupling of alkynes to the intermediate metallacyclopentadiene species.[9] In an attempt to improve regioselectivity, we changed the electronic and steric features of the ethynylpyridine using **3c**.[14] Regioselectivity (3-substituted-2,2′-bipy *vs* 2-substituted-3,2′-

† This paper is dedicated to the memory of Prof. Ignacio Ribas Marqués.

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Scheme 1

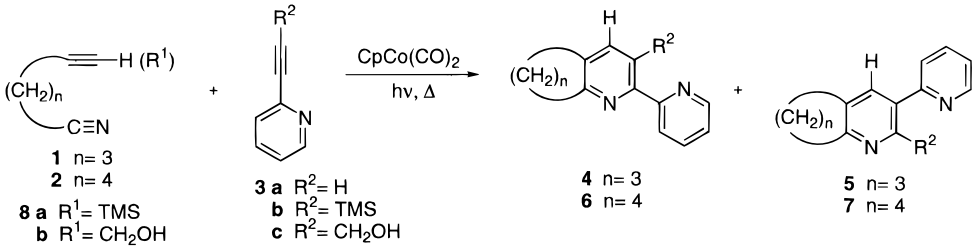
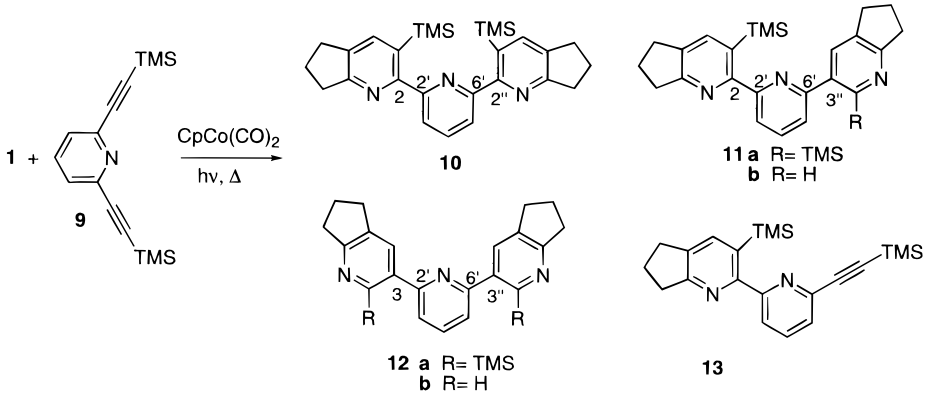


Table 1. Results of Cocyclization of 1 with 3b

entry	conditions[a]	yield,[b] %	**4b**:**5a** ratio[c]	**3b** recov, %
1	**1** + **3b** (1.2 equiv) + [Co] 15% (method A)	25	1:1.5	69
2	**1** + **3b** (1.2 equiv) + [Co] 15% (method B)	51	1:1.4	41
3	**1** (1.2 equiv) + **3b** + [Co] 15% (method B)	35	1:1.3	54
4	**1** (1.5 equiv) + **3b** + [Co] 30% (method B)	43	1:1.3	52
5	**1** (2.0 equiv) + **3b** + [Co] 30% (method B)	74	1:1.1	12
6	**1** (1.5 equiv) + **3b** + [Co] 30% (method C)	61	1:1.2	–

[a] See Experimental Section. Regardless of the method used, 3−9% yields of 2-(3-cyanopropyl)- and/or 3-(3-cyanopropyl)cyclopenta[*b*]-pyridines were also obtained.[22] [b] Isolated yields of **4b** + **5a** after separation by column chromatography or preparative TLC (silica gel). [c] **5a** was obtained by desilylation of **5b** during purification/isolation steps.

Scheme 2



bipy) was indeed slightly improved (the **4c**:**5c** ratio was 4:1), but total yield of bipyridines was much reduced (19%).[9b,15]

On the other hand, we were unable to synthesize bipyridines in which one of the pyridine rings bears two substituents in addition to the alkyl ring. Under the conditions of method B, the reactions between 6-(trimethylsilyl)-5-hexynenitrile (**8a**) and **3a** and between 7-hydroxy-5-heptynenitrile (**8b**) and **3b** afforded unaltered starting alkynenitriles,[16] as did irradiation of **8b** alone.[17] The failure to form pyridines, benzenes, and/or cyclobutadienylcobalt complexes suggests that the reaction requires a terminal C−H on the alkynenitrile. We are currently investigating whether the cyano group plays a role in the formation of the intermediate metallacycle,[9] and whether oxidative addition of Co(I) to the alkynenitrile C−H bond is necessary for formation of the intermediate cobaltocycle.[18]

In view of the above results we decided to explore the use of the same methodology for synthesis of terpyridines, which are ligands of outstanding interest in the field of supramolecular coordination chemistry[1] and certain areas of bioorganic chemistry.[19] Cocyclization of **1** with 2,6-bis[(trimethylsilyl)ethynyl]pyridine (**9**)[10a] in the presence of 30% of catalyst afforded 2,2′:6′,2″-, 2,2′:6′,3″-, and 3,2′:6′,3″-terpyridines **10** (8%), **11b** (31%), **12b** (25%), and 2,2′-bipyridine **13** (21%) (Scheme 2).

Although the appearance of all possible regioisomers was perhaps unfortunate, the total yield was good (85%),[20] and this reaction is certainly competitive with other methods of synthesizing the symmetric 3,3″-substituted terpyridine **10**. The appearance of bipyridine **13** may have been due to the replacement of one of the TMS-ethynyl moieties of **9** with a 2,2′-bipyridine unit having reduced the electron density and hence the reactivity of the remaining alkyne or it may have been due to steric hindrance to the formation of the second metallacycle intermediate.

To sum up, we have developed a short alternative to existing methods for the synthesis of annelated 3-substituted bipyridines and symmetric 3,3″-substituted terpyridines, which are of interest as building blocks for the assembly of supramolecular coordination compounds. The

(15) The two regioisomers **4c** and **5c** were identified by NOE experiments.

(16) These results are in line with those obtained by other authors.[9] The main side product in the reaction of **8a** with **3a** was the benzene derivative caused by self-trimerization of **3a**.

(17) This result contrasts with the ready transformation of **1** into 2-(3-cyanopropyl)- and 3-(3-cyanopropyl)cyclopenta[*b*]pyridines.[22]

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(20) All these isomers were easily separated by column chromatography or preparative TLC on silica gel.

coordination chemistry of the new ligands and the properties of their complexes are currently being studied and will be the subject of forthcoming reports. It is hoped that future work will be able to generalize the new synthetic method to the preparation of heterooligopyridines, chiral bipyridines, and other potentially valuable products.[12,21]

Experimental Section

General. All reactions were carried out under argon. Toluene was distilled from Na/benzophenone. Slow additions were carried out using a syringe pump (Harvard 11). Melting points are uncorrected. ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$.

General Procedures for the Cobalt(I)-Catalyzed [2 + 2 + 2] Cycloadditions. Method A. A solution of **1** (0.3 g, 3.2 mmol), **3b** (0.68 g, 3.87 mmol) and [$CpCo(CO)_2$] (59.2 μL, 0.48 mmol) in toluene (5 mL) was slowly added over 11 h, via a syringe pump, to stirred toluene (100 mL) under Ar in a round-bottomed flask equipped with a reflux condenser. During the addition the reaction vessel was irradiated with a Philips PF 808 300W tungsten slide projector lamp placed ca. 5 cm from the center of the flask and operated at 225 W. Heating and irradiation continued for 1 h after addition was complete. The volatile components were removed under vacuum, and the residue was chromatographed on silica gel (10:90 to 100:0, EtOAc/hexane).

Method B. A solution of **3b** (0.3 g, 1.7 mmol), **1** (0.32 g, 3.42 mmol), and [$CpCo(CO)_2$] (63 μL, 0.51 mmol) in toluene (100 mL) was irradiated for 7 h in the same conditions as described for method A. Workup as in method A.

Method C. A solution of [$CpCo(CO)_2$] (32 μL, 0.26 mmol) in toluene (5 mL) was slowly added over 6 h, via a syringe pump, to a stirred solution of **3b** (0.15 g, 0.85 mmol) and **1** (0.12 g, 1.28 mmol) in toluene (15 mL). The reaction vessel was irradiated as in the previous methods. Heating and light irradiation continued for 4 h after addition was complete. Workup as in method A, using preparative TLC on silica gel for chromatography.

2-(2-Pyridyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridine (4a). Methods used: A or B. Yield, 11%. White powder (from hexane), mp 78−79 °C. UV/vis (CH_2Cl_2) λ_{max} = 246, 296 nm. IR (KBr) ν 2956, 1575, 1428, 784 cm^{-1}. MS *m*/*z* (relative intensity) 196 (M^+, 92), 195 (100), 168 (8). ^{1}H NMR δ 8.67 (m, 1H), 8.34 (d, J = 7.8 Hz, 1H), 8.11 (d, J = 7.8 Hz, 1H), 7.78 (dt, J = 7.8, 1.8 Hz, 1H), 7.61 (d, J = 7.8 Hz, 1H), 7.29−7.24 (m, 1H), 3.09 (t, J = 7.5 Hz, 2H), 2.98 (t, J = 7.5 Hz, 2H), 2.23−2.13 (m, 2H). ^{13}C NMR δ 165.5 (C), 156.8 (C), 154.6 (C), 149.1 (CH), 137.3 (C), 136.8 (CH), 132.7 (CH), 123.1 (CH), 120.9 (CH), 118.8 (CH), 34.2 (CH_2), 30.5 (CH_2), 23.2 (CH_2). HRMS calcd for $C_{13}H_{12}N_2$ 196.10005; found 196.09997.

2-(2-Pyridyl)-3-(trimethylsilyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridine (4b). Methods used: A, B, or C. Yield, 35%. White crystals (from methanol), mp 75−76 °C. UV/vis (CH_2Cl_2) λ_{max} = 256, 300 nm. IR (KBr) ν 2952, 1581, 1246, 841 cm^{-1}. MS *m*/*z* (relative intensity) 268 (M^+, 2), 253 (100), 223 (10), 210 (7). ^{1}H NMR δ 8.57 (m, 1H), 8.12 (d, J = 7.8 Hz, 1H), 7.86 (s, 1H), 7.77 (dt, J = 7.8, 1.8 Hz, 1H), 7.28−7.23 (m, 1H), 3.07 (t, J = 7.5 Hz, 2H), 2.98 (t, J = 7.5 Hz, 2H), 2.15 (q, J = 7.5 Hz, 2H), 0.19 (s, 9H). ^{13}C NMR δ 165.8 (C), 160.5 (C), 159.3 (C), 147.6 (CH), 140.2 (CH), 137.1 (CH), 136.3 (C), 131.3 (C), 123.3 (CH), 122.8 (CH), 34.7 (CH_2), 31.0 (CH_2), 23.6 (CH_2), 1.9 (CH_3). HRMS calcd for $C_{16}H_{20}N_2Si$ 268.13958; found 268.13956.

[2-(2-Pyridyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridin-3-yl]-methanol (4c). Methods used: B or C. Yield, 15%. Colorless crystals (from ethyl acetate−hexane), mp 108−110 °C. UV/vis (CH_2Cl_2) λ_{max} = 246, 294 nm. IR (film) ν 3307, 2954, 1590, 1423, 1031 cm^{-1}.^{1}H NMR δ 8.61 (m, 1H), 8.21 (d, J = 7.9 Hz, 1H), 7.88 (dt, J = 7.9, 1.5 Hz, 1H), 7.58 (s, 1H), 7.58−7.28 (m, 1H), 6.69 (broad s, 1H), 4.51 (s, 2H), 3.07 (t, J = 7.6 Hz, 2H), 2.99 (t, J = 7.6 Hz, 2H), 2.18 (q, J = 7.6 Hz, 2H). ^{13}C NMR δ 164.8 (C), 158.2 (C), 154.2 (C), 147.3 (CH), 137.5 (C + CH), 135.1 (CH), 133.5 (C), 124.4 (CH), 123.0 (CH), 63.9 (CH_2), 34.0 (CH_2), 30.4 (CH_2), 23.2 (CH_2). HRMS calcd for $C_{14}H_{14}N_2O$ 226.11061; found 226.11054.

3-(2-Pyridyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridine (5a). Methods used: A, B, or C. Yield, 39%. Colorless crystals (from hexane), mp 79−80 °C. UV/vis (CH_2Cl_2) λ_{max} = 248, 290 nm. IR (KBr) ν 2954, 1568, 1422, 780 cm^{-1}. MS *m*/*z* (relative intensity) 196 (M^+, 99), 195 (100), 168 (13), 58 (44). ^{1}H NMR δ 8.87 (s, 1H), 8.67 (m, 1H), 8.12 (s, 1H), 7.77−7.62 (m, 2H), 7.26−7.21 (m, 1H), 3.05 (t, J = 7.6 Hz, 2H), 2.99 (t, J = 7.6 Hz, 2H), 2.16 (q, J = 7.6 Hz, 2H). ^{13}C NMR δ 166.8 (C), 156.0 (C), 150.3 (CH), 146.7 (CH), 137.6 (C), 137.3 (CH), 133.2 (C), 130.9 (CH), 122.8 (CH), 120.9 (CH), 34.4 (CH_2), 31.0 (CH_2), 23.6 (CH_2). HRMS calcd for $C_{13}H_{12}N_2$ 196.10005; found 196.10008.

[3-(2-Pyridyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridin-2-yl]-methanol (5c). Methods used: B or C. Yield, 4%. Yellowish crystals (from ethyl acetate−hexane), mp 85−87 °C. UV/vis (CH_2Cl_2) λ_{max} = 246, 288 nm. IR (film) ν 3404, 2926, 1592, 1429, 1027 cm^{-1}.^{1}H NMR δ 8.67 (m, 1H), 7.83 (dt, J = 7.9, 1.8 Hz, 1H), 7.67 (s, 1H), 7.5 (d, J = 7.9 Hz, 1H), 7.32 (m, 1H), 4.68 (s, 2H), 3.09 (t, J = 7.6 Hz, 2H), 3.00 (t, J = 7.6 Hz, 2H), 2.19 (q, J = 7.6 Hz, 2H). ^{13}C NMR δ 165.2 (C), 157.7 (C), 156.0 (C), 148.8 (CH), 137.2 (CH), 136.2 (C), 133.5 (CH), 132.1 (C), 123.6 (CH), 122.4 (CH), 64.8 (CH_2), 34.0 (CH_2), 30.4 (CH_2), 23.3 (CH_2). HRMS calcd for $C_{14}H_{14}N_2O$ 226.11061; found 226.11062.

2-(2-Pyridyl)-5,6,7,8-tetrahydroquinoline (6a). Methods used: A or B. Yield, 9%. Brown oil. UV/vis (CH_2Cl_2) λ_{max} = 244, 294 nm. IR (film) ν 2932, 1556, 1453, 787 cm^{-1}. MS *m*/*z* (relative intensity) 210 (M^+, 100), 209 (77), 195 (11), 182 (19). ^{1}H NMR δ 8.62 (m, 1H), 8.34 (d, J = 7.9 Hz, 1H), 8.06 (d, J = 7.9 Hz, 1H), 7.72 (dt, J = 7.9, 1.6 Hz, 1H), 7.44 (d, J = 7.9 Hz, 1H), 7.24−7.20 (m, 1H), 2.97 (t, J = 6.3 Hz, 2H), 2.78 (t, J = 6.3 Hz, 2H), 1.94−1.86 (m, 2H), 1.84−1.77 (m, 2H). ^{13}C NMR δ 157.2 (C), 157.1 (C), 153.7 (C), 149.4 (CH), 137.9 (CH), 137.1 (CH), 132.9 (C), 123.5 (CH), 121.3 (CH), 118.7 (CH), 33.2 (CH_2), 29.1 (CH_2), 23.6 (CH_2), 23.1 (CH_2). HRMS calcd for $C_{14}H_{14}N_2$ 210.11570; found 210.11575.

2-(2-Pyridyl)-3-(trimethylsilyl)-5,6,7,8-tetrahydroquinoline (6b). Method used: C. Yield, 31%. Pale yellow crystals (from hexane), mp 78−79 °C. UV/vis (CH_2Cl_2) λ_{max} = 250, 290 nm. IR (KBr) ν 2925, 1586, 1241, 839 cm^{-1}. MS *m*/*z* (relative intensity) 282 (M^+, 1), 267 (100). ^{1}H NMR δ 8.57 (m, 1H), 8.16 (d, J = 7.8 Hz, 1H), 7.76 (dt, J = 7.8, 1.7 Hz, 1H), 7.69 (s, 1H) 7.27−7.22 (m, 1H), 2.98 (t, J = 6.2 Hz, 2H), 2.82 (t, J = 6.2 Hz, 2H), 1.97−1.80 (m, 4H), 0.21 (s, 9H). ^{13}C NMR δ 158.6 (2 C), 156.7 (C), 147.1 (CH), 145.0 (CH), 136.5 (CH), 131.0 (C), 130.5 (C), 122.8 (CH), 122.2 (CH), 32.5 (CH_2), 28.6 (CH_2), 23.2 (CH_2), 22.9 (CH_2), 1.4 (CH_3). HRMS calcd for $C_{17}H_{22}N_2Si$ 282.15523; found 282.15536.

3-(2-Pyridyl)-5,6,7,8-tetrahydroquinoline (7a). Methods used: A, B or C. Yield, 45%. Brown oil. UV/vis (CH_2Cl_2) λ_{max} = 250, 290 nm. IR (film) ν 2931, 1587, 1433, 784 cm^{-1}. MS *m*/*z* (relative intensity) 210 (M^+, 100), 209 (79), 181 (20). ^{1}H NMR δ 8.81 (s, 1H), 8.59 (m, 1H), 7.91 (s, 1H), 7.64 (m, 2H), 7.17−7.12 (m, 1H), 2.88 (t, J = 6.1 Hz, 2H), 2.75 (t, J = 6.1 Hz, 2H), 1.85−1.71 (m, 4H). ^{13}C NMR δ 158.0 (2 C), 155.2 (C), 149.8 (CH), 145.0 (CH), 136.8 (CH), 134.9 (CH), 132.2 (C), 122.3 (CH), 120.2 (CH), 32.2 (CH_2), 28.7 (CH_2), 22.9 (CH_2), 22.5 (CH_2). HRMS calcd for $C_{14}H_{14}N_2$ 210.11570; found 210.11581.

2-[6-[3-(Trimethylsilyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridin-2-yl]-2-pyridyl]-3-(trimethylsilyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridine (10). Method used: B. Yield, 8%. Yellowish crystals (from hexane), mp 164−166 °C. UV/vis (CH_2Cl_2) λ_{max} = 232 (sh), 252, 296 nm. IR (KBr) ν 2946, 1570, 1365, 1246, 843 cm^{-1}. MS *m*/*z* (relative intensity) 457 (M^+, 9), 442 (100), 368 (7), 354 (12). ^{1}H NMR δ 7.86 (m, 1H), 7.77 (m, 4H), 3.05 (t, J = 7.5 Hz, 4H), 2.97 (t, J = 7.5 Hz, 4H), 2.15 (q, J = 7.5 Hz, 4H), −0.15 (s, 18H). ^{13}C NMR δ 165.0 (C), 161.6 (C), 159.5 (C), 139.2 (CH), 137.2 (CH), 135.2 (C), 131.3 (C), 122.5 (CH), 34.3 (CH_2), 30.5 (CH_2), 22.9 (CH_2), 0.51 (CH_3). HRMS calcd for $C_{27}H_{35}N_3Si_2$ 457.23696; found 457.23688.

2-[6-(6,7-Dihydro-5*H*-cyclopenta[*b*]pyridin-3-yl)-2-pyridyl]-3-(trimethylsilyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridine (11b). Method used: B. Yield, 31%. Pale brown crystals (from ethyl acetate−hexane), mp 200−202 °C. UV/vis (CH_2Cl_2)

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(22) These side products are formed by self-trimerization of the starting alkynenitrile: Selimov, F. A.; Khafizov, V. R.; Dzhemilev, V. M. *Bull. Acad. Sci. USSR* **1983**, *32*, 1709.

λ_{max} = 232 (sh), 250, 295 nm. IR (KBr) ν 2948, 1572, 1411, 1243, 839 cm^{-1}; MS *m*/*z* (relative intensity) 385 (M^+, 4), 370 (100), 338 (2), 185 (7), 58 (6). ^1H NMR δ 8.87 (s, 1H), 8.07 (s, 1H), 7.85−7.79 (m, 2H), 7.68−7.64 (m, 2H), 3.07−2.86 (m, 8H), 2.17−2.04 (m, 4H), −0.05 (s, 9H). ^{13}C NMR δ 166.2 (C), 165.4 (C), 161.5 (C), 161.2 (C), 154.5 (C), 146.7 (CH), 139.3 (CH), 137.4 (CH), 136.9 (C), 135.8 (C), 132.8 (C), 131.1 (CH), 130.8 (C), 122.7 (CH), 120.3 (CH), 34.3 (CH_2), 33.9 (CH_2), 30.5 (2 x CH_2), 23.1 (CH_2), 23 (CH_2), 0.5 (CH_3). HRMS calcd for $C_{24}H_{27}N_3Si$ 385.19743; found 385.19748.

3-[6-(6,7-Dihydro-5*H*-cyclopenta[*b*]pyridin-3-yl)-2-pyridyl]-6,7-dihydro-5*H*-cyclopenta[*b*]pyridine (12b). Method used: B. Yield, 25%. Brown powder (from ethyl acetate−dichloromethane), mp 210−212 °C. UV/vis (CH_2Cl_2) λ_{max} = 248, 286, 300 (sh) nm. IR (KBr) ν 2924, 1576, 1444, 1387, 812 cm^{-1}; MS *m*/*z* (relative intensity) 313 (M^+, 100), 285 (3), 185 (10), 155 (5), 149 (7), 58 (14). ^1H NMR δ 9.0 (broad s, 2H), 8.24 (broad s, 2H), 7.81 (t, *J* = 8.3 Hz, 1H), 7.67 (d, *J* = 8.3 Hz, 2H), 3.05 (t, *J* = 7.6 Hz, 4H), 3.02 (t, *J* = 7.6 Hz, 4H), 2.17 (q, *J* = 7.6 Hz, 4H). ^{13}C NMR δ 166.8 (C), 155.6 (C), 146.6 (CH), 137.7 (C + CH), 133.0 (C), 130.5 (CH), 118.8 (CH), 34.1 (CH_2), 30.6 (CH_2), 23.2 (CH_2). HRMS calcd for $C_{21}H_{19}N_3$ 313.15790; found 313.15802.

2-[6-[2-(Trimethylsilyl)ethynyl]-2-pyridyl]-3-(trimethylsilyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridine (13). Method used: B. Yield, 21%. White powder (from hexane), mp 122−124 °C. UV/vis (CH_2Cl_2) λ_{max} = 230 (sh), 254, 300 nm. IR (KBr) ν 2924, 2159, 1568, 1246, 842 cm^{-1}; MS *m*/*z* (relative intensity) 349 (M^+ − 15, 100), 261 (5), 167 (8). ^1H NMR δ 8.13 (d, *J* = 7.7 Hz, 1H), 7.86 (s, 1H), 7.71 (t, *J* = 7.7 Hz, 1H), 7.40 (d, *J* = 7.7 Hz, 1H), 3.05 (t, *J* = 7.4 Hz, 2H), 2.97 (t, *J* = 7.4 Hz, 2H), 2.14 (q, *J* = 7.4 Hz, 2H), 0.27 (s, 9H), 0.25 (s, 9H). ^{13}C NMR δ 165.4 (C), 159.3 (C), 159.2 (C), 141.0 (C), 139.9 (CH), 136.7 (CH), 136.2 (C), 131.4 (C), 126.3 (CH), 122.0 (CH), 103.9 (C), 95.2 (C), 34.2 (CH_2), 30.6 (CH_2), 23.1 (CH_2), 1.3 (CH_3), −0.4 (CH_3). HRMS calcd for $C_{20}H_{25}N_2Si_2$ (M^+ − 15) 349.15563; found 349.15559.

6-(Trimethylsilyl)-5-hexynenitrile (8a). A solution of BuLi in hexane (4.35 mL, 1.25 M, 5.44 mmol) was slowly added to a solution of **1** (0.5 g, 5.44 mmol) in dry THF (10 mL) cooled at −78 °C. The mixture was stirred for 1 h, and trimethylsilyl chloride (0.83 mL, 0.71 g, 6.52 mmol) was added. The resulting solution was kept at −78 °C for 4 h. The reaction was quenched with H_2O and $HNaCO_3$ (10 mL) and extracted with ether (3 × 10 mL). The combined organic layers were dried and concentrated, and the residue was chromatographed on silica gel (ethyl acetate/hexane 1:9) to afford **8a** (0.64 g, 72%): pale yellow oil; ^1H NMR δ 2.47 (t, *J* = 7 Hz, 2H), 2.38 (t, *J* = 7 Hz, 2H), 1.85 (q, *J* = 7 Hz, 2H), 0.14 (s, 9H). ^{13}C NMR δ 119.1 (C), 103.9 (C), 86.8 (C), 24.4 (CH_2), 18.9 (CH_2), 15.9 (CH_2), −0.1 (CH_3).

7-Hydroxy-5-heptynenitrile (8b). A solution of BuLi in hexane (8.27 mL, 1.3 M, 10.7 mmol) was slowly added to a solution of **1** (1 g, 10.7 mmol) in dry THF (6 mL) cooled at −78 °C. The mixture was stirred for 1 h and cannulated over a suspension of paraformaldehyde (1.16 g, 12.9 mmol) in dry THF (2 mL) at −78 °C. The resulting solution was allowed to reach rt and stirred for 4 h. The reaction was quenched with H_2O (10 mL) and extracted with ether (4 × 10 mL). The combined organic layers were washed with brine, dried, and concentrated, and the residue was chromatographed on silica gel (ethyl acetate/hexane 4:6) to afford **8b** (0.93 g, 70%): pale yellow oil; ^1H NMR δ 4.20 (s, 2H), 2.48 (t, *J* = 7 Hz, 2H), 2.41−2.34 (m, 2H), 1.83 (q, *J* = 7 Hz, 2H). ^{13}C NMR δ 119.1 (C), 83.0 (C), 80.3 (C), 50.8 (CH_2), 24.2 (CH_2), 17.5 (CH_2), 16.0 (CH_2).

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Supporting Information Available: Spectroscopic data (UV, IR, MS, ^1H NMR, ^{13}C NMR, HRMS) and copies of the ^1H NMR and ^{13}C NMR spectra (27 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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