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AUXILIARY SILICON IN REGIOSELECTIVE COBALT CATALYZED PROTOBERBERINE SYNTHESES

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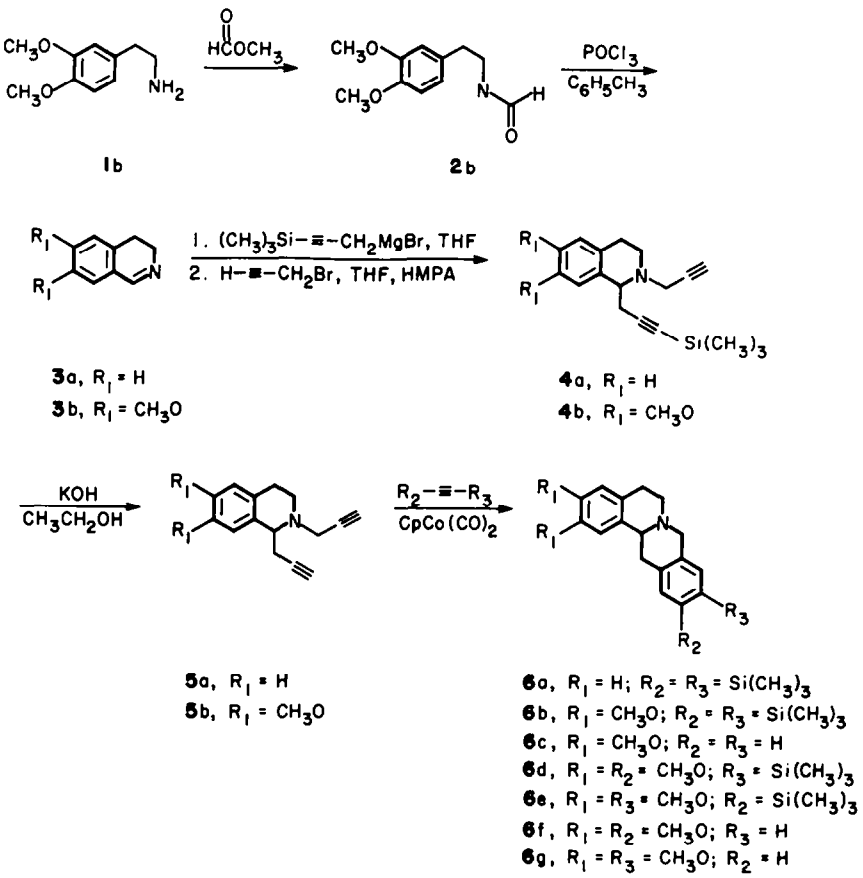
Abstract—η^5-Cyclopentadienyl dicarbonyl cobalt catalyzes the cocyclization of 1,2-bis(propargyl)-1,2,3,4-tetrahydroisoquinolines **4b** and **5** with alkynes to provide a novel synthetic entry into the tetrahydroprotoberberine nucleus. By judicious choice of trimethylsilyl substituents, regiocontrol in the D-ring can be achieved. Reaction of **4b** with benzonitrile in the presence of the catalyst furnishes the rare isoquino[2, 1-*b*]-2,6-naphthyridine framework, also regioselectively.

The protoberberine nucleus has received continued synthetic attention because of its varied physiological activity[1,2] and as a model molecular framework on which to exercise advances in synthetic methodology directed at the construction of heteropolycycles.[1,3] Although the tetracycle has been approached in a variety of ways, none of them have generated in their key step the C and D ring simultaneously. We report here a total synthesis of tetrahydroprotoberberines, in which this novel strategy has been successful by employing the ability of η^5-cyclopentadienyl dicarbonyl cobalt to effect the cotrimerization of α, ω-diynes with monoalkynes to give annulated benzenes[4] and with nitriles to give the corresponding pyridines.[5] The reaction proceeds well in the presence of the propargylic tertiary N in the starting diyne and can be extensively controlled by using the terminal trimethylsilyl substituent as a protecting and sterically regiodirecting group, as well as a leaving group in electrophilic substitutions. Since it provides access to a defined and varied substitution pattern in the D-ring of the protoberberine structure, the method significantly expands earlier synthetic capability.

RESULTS AND DISCUSSION

Our approach to the required 1,2 - bis(propargyl) - 1,2,3,4 - tetrahydroisoquinoline starting materials is outlined in Scheme 1 and utilizes the successive action of both propargyl anion as well as cation equivalents on the imine **3**. Two series of compounds were investigated: one without substituents in what is to become the A-ring of the desired product (series 1), and one in which the 2,3-positions bear methoxy groups (series 2). The 3,4-dihydroisoquinolines **3** were prepared in two ways. In series 1 Rapoport's method (1. N-chlorosuccinimide, 2. KOH, CH_3CH_2OH) for the transformation of piperidine to Δ^1-piperideine[6] was applied to 1,2,3,4-tetrahydroisoquinoline to give **3a** in 98% yield. In series 2, homoveratrylamine (**1b**) was quantitatively formylated with methyl formate and the resulting **2b** subjected to Bischler–Napieralski cyclization[7] to afford 3,4 - dihydro - 6,7 - dimethoxyisoquinoline (**3b**) in 89% yield. A variety of conditions were employed in the conversion of **3** to **4**. In a nonoptimized stepwise sequence **3a** was first exposed to the Grignard reagent derived from 3 - bromo - 1 - trimethylsilylpropyne[8] to give 1 - (3 - trimethylsilyl - 2 - propynyl) - 1,2,3,4 - tetrahydroisoquinoline (46%) which was subsequently propargylated[9] with 1/2 equivalent of 3-bromopropyne to furnish **4a** in 66% yield. Similarly **3b** was converted to **4b** in 35% overall yield. Since this approach was unsatisfactory both with respect to yields and to conversion of starting materials, a one-step procedure was developed for **3b** in which Grignard addition was immediately followed by propargylation facilitated by the presence of 1.5 equivalents of HMPA. This led to the isolation of 67% **4b**. The silyl group was now removed (1% KOH, CH_3CH_2OH, 100%) and the stage set for the cobalt catalyzed cocyclization with the sterically hindered bis(trimethylsilyl)ethyne, previously successfully employed in annulated benzene syntheses.[4] Gratifyingly, reaction of either **5a** or **5b** with the bissilylated monoalkyne gave the respective tetrahydroprotoberberine derivatives **6a** and **6b** in excellent yields (87% and 93%, respectively). These and all other new compounds in this account were fully characterized and analyzed unless mentioned otherwise (Experimental). In addition to their characteristic ^{1}H-NMR and mass spectra, tetrahydroberberines exhibit diagnostic peaks in the IR spectra between 2750 and 2800 cm^{-1} ("Bohlmann bands").[1] Further chemical structural proof for **6b** was obtained by quantitative protodesilylation (HBr, CH_2Br_2) which led to the known **6c**.[1,3e]

It was now of interest to determine whether ring D could be constructed regioselectively when employing an unsymmetrical alkyne. Such a study had never been carried out systematically using α, ω-diynes although we had noted earlier that 1 - trimethylsilyl - 1,5 - hexadiyne cotrimerized with two such alkyne derivatives to give predominantly the more hindered 3,4-disubstituted benzocyclobutenes.[4a,10] This result was rationalized by invoking a mechanism in which the unsubstituted end of the diyne and the monoyne oxidatively coupled in the coordination sphere of the metal to give only one regioisomeric cobaltacyclopentadiene, both substituents being positioned α to the metal.[10] Subsequent insertion of the appended third alkyne unit would then necessarily lead to the observed product. Similar intermediates have been postulated to explain the regioselectivity found in enyne cocyclizations[11] and in the synthesis of cycloalka[1,2-*b*]pyridines[12] using cobalt catalysis. In addition to the question of control of the ring D substitution



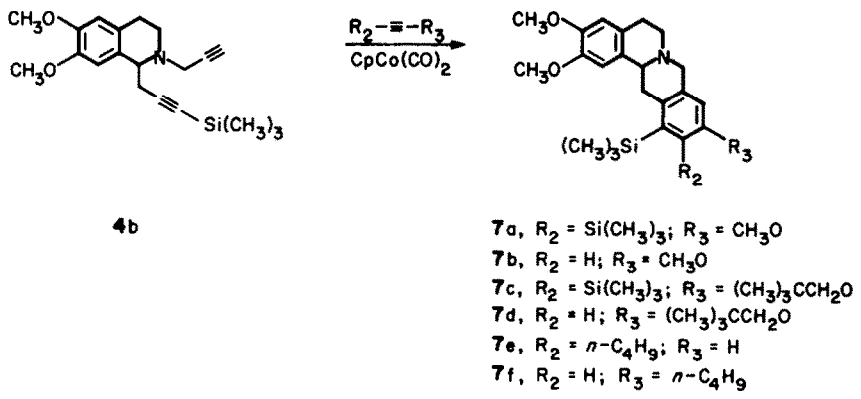
Scheme 1. Cobalt mediated total synthesis of tetrahydroprotoberberines.

pattern, a further point of concern with respect to our approach to protoberberines was the presence of oxygen functionality in that part of the molecule in most natural and/or physiologically active derivatives. To address both of these problems simultaneously we decided to initially explore the cyclization of **5b** with trimethylsilylmethoxyethyne in the presence of $CpCo(CO)_2$.

The reaction was carried out using high dilution syringe pump addition conditions in refluxing *m*-xylene while irradiating with an ordinary 250 W GE–ENH slide projector lamp. This protocol ensures the most efficient activation of the catalyst by accelerating CO dissociation. A 1:1 mixture of the two regioisomers **6d** and **6e** was obtained in 68% yield, separated by flash chromatography.[13] Thus, not surprisingly, no regioselectivity was evident in this reaction. At this point the absolute structural assignment for the two isomers was tentative, the spectral data not allowing for a definite choice of one substitution pattern for either compound. A simple solution to this problem appeared to be the correlation of each isomer with the known trimethoxyprotoberberines **6f**[3l,14] and **6g**[15] by protodesilylation. This was in fact carried out (CF_3CO_2H–CCl_4, 100%), however, comparison of the spectral data of the respective products (and the m.ps of their hydrochloride salts) with the information retrieved from the literature appeared associated with sufficient ambiguity that an alternative structural proof seemed desirable.

In order to perhaps introduce more steric bias into the reaction and to possibly be able to unambiguously assign the structures of the two isomers **6d** and **6e**, the cyclization potential of the trimethylsilyl derivative **4b** was explored (Scheme 2). Indeed, reaction of this diyne with trimethylsilylmethoxyethyne gave only *one* protoberberine derivative in 58% yield. The structural assignment as a cotrimer was readily made based on the spectral and analytical data. However, the determination of its substitution sequence in the D-ring posed an interesting puzzle. Inspection of the molecule suggests that a solution to this problem might be found if selective protomonodesilylation were possible. For example, should the product have structure **7a** then selective hydrolysis of the trimethylsilyl group at C_{11} (R_2) (being located *ortho* to the methoxy substituent) should give a new compound, isomeric to **6d** and **6e**, with two ring D protons exhibiting *meta*-coupling in the NMR spectrum. On the other hand, should protodesilylation for some reason occur at C_{12} (*meta* to the OMe group) **6d** or **6e** would be generated. The latter result would not allow one to come to any conclusions regarding the structure of either isomer nor their potential precursor (*vide infra*).

In contrast, should the cyclization have proceeded with regioselectivity opposite to the one shown in **7a** (e.g. R_2=MeO, R_3=$SiMe_3$) then selective removal of the trimethylsilyl group at C_{10}(R_3) would give yet another isomer of **6d** or **6e**, presumably distinguishable from the one mentioned above by the *ortho*-coupling anticipated for the ring D protons. However, if the desilylation were



4b

7a, $R_2 = Si(CH_3)_3$; $R_3 = CH_3O$
7b, $R_2 = H$; $R_3 = CH_3O$
7c, $R_2 = Si(CH_3)_3$; $R_3 = (CH_3)_3CCH_2O$
7d, $R_2 = H$; $R_3 = (CH_3)_3CCH_2O$
7e, $R_2 = n\text{-}C_4H_9$; $R_3 = H$
7f, $R_2 = H$; $R_3 = n\text{-}C_4H_9$

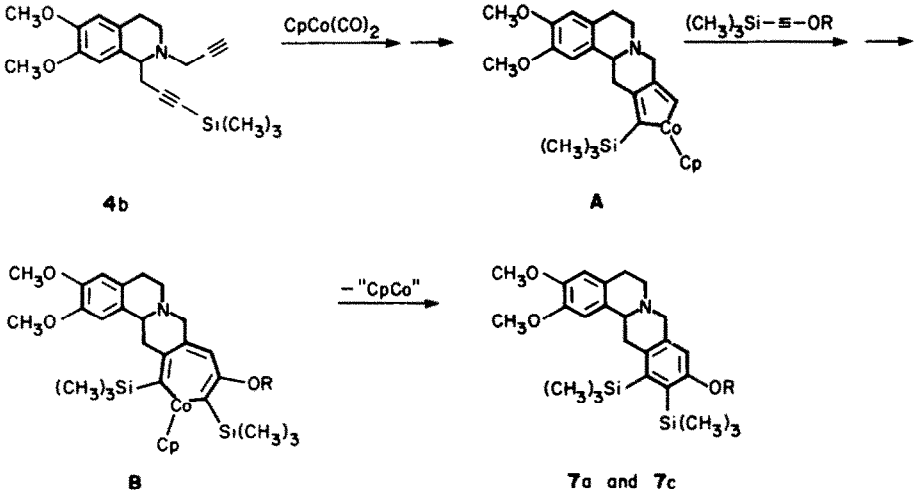
Scheme 2. Regioselective cooligomerization of **4b** with unsymmetrical alkynes.

to occur at C_{12} this would again furnish either **6d** or **6e** as above, making any structural distinction difficult. Fortunately, in the event, treatment of the bissilylated cocyclization product with 10% trifluoroacetic acid in CCl_4 for 12 hr gave 75% mono and 24% bisdesilylation, the former clearly resulting in **7b** [$J_{meta}(H_{9,11}) = 2.3$ Hz], hence the latter unambiguously is **6g**. Therefore the structure of the starting material is **7a**. This means that the regioselectivity of the cocyclization of **4b** is in favor of the more hindered isomer as observed in the two cases examined previously.[10] Similarly, cocyclization of **4b** with trimethylsilylneopentoxyethyne [prepared in two steps from chloroacetaldehyde dimethyl acetal by acid catalyzed transacetalization[16] to the dineopentyl acetal (92%), followed by sequential treatment with lithium diisopropylamide in ether, and trimethylsilyl chloride (84%)] gave only **7c** (61%), which was selectively monodesilylated to **7d** (99%).

In order to further delineate the scope of the observed regiochemistry, **4b** was subjected to cyclization with 1-hexyne. A 1:1 ratio of the regioisomers **7e** and **7f** was isolated, separated by preparative thin layer chromatography on silica gel. Unfortunately, the combined yield of products in this reaction was only 5%, negating any mechanistic significance that may be attached to the seeming lack of selectivity.

A reasonable mechanistic rationale for the exclusive formation of **7a** and **7c** in the cocyclization of **4b** with the two respective silylalkoxyethynes is presented in Scheme 3. It is likely that the reaction proceeds through initial intramolecular oxidative coupling of the alkyne units on the diyne to give intermediate **A**. Subsequent complexation of the alkoxyalkyne followed by insertion into the Co–C bond then gives **B**. In order to explain the regiochemical outcome of the cyclization one has to postulate that the latter occurs such as to place the silyl-bearing C atom next to the metal. This conforms with other experimental evidence[4,10–12,17] and may have electronic origins.[18] Extrusion of the cobalt from **B** then forces the two silyl groups to come to be located next to each other.

The successful outcome of the above experiments suggested to us that it might also be possible to employ **4b** in regioselective cocyclizations with nitriles.[5] For example, we had noted earlier[5] that 1,7-decadiyne cotrimerized with valeronitrile to give predominantly (17:1 selectivity) the 2,6-dialkylated tetrahydroisoquinoline derivative. This could be rationalized by invoking incorporation of the nitrile into the initially

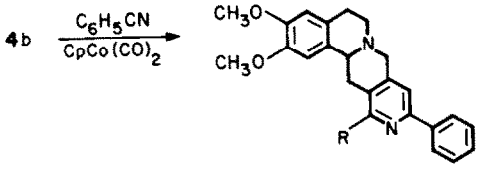


4b A B 7a and 7c

Scheme 3. Suggested mechanism for the regiospecific formation of **7a** and **7c**.

formed metallacyclopentadiene by insertion into the less hindered (substituted) Co–C bond and placing the N next to the metal.[19] One might anticipate that the presence of a trimethylsilyl substituent would exert even stronger regiocontrol. In the case of **4b**, such a reaction would result in the evidently[20] exceedingly rare isoquino[2,1-*b*] - 2,6 - naphthyridine nucleus. In fact, the very few reported D-ring azaprotoberberines[21] are all of recent origin, including some alkaloids isolated from the seeds of *Alangium lamarckii* Thw.[22]

Catalytic cocyclization of **4b** with benzonitrile indeed gave the desired new heterocycle **8a** (Scheme 4). The presence of this substance could be readily ascertained by NMR spectroscopy, particularly due to the presence of a singlet absorption at δ 7.36 pinpointing the direction of the (in this case complete) regioselectivity. On attempted chromatographic purification (silica or neutral alumina) complete protodesilylation occurred to furnish **8b** in 74% overall yield from **4b**. The most characteristic feature in the NMR spectrum of this compound was the appearence of a new peak at δ 8.47 typical for a pyridine proton located next to the heteroatom. Since a large variety of nitriles are known to undergo such cocyclizations,[5] it should be possible to gain access to other derivatives of this ring system. Modification of **4b** such as to place the silyl group on the other alkyne unit would also allow the preparation of the regioisomeric 2,7-naphthyridines. This strategy could also be applied to the synthesis of other protoberberines.



8a, R = $Si(CH_3)_3$
8b, R = H

Scheme 4. Cobalt catalyzed synthesis of isoquino[2,1-*b*] - 2,6 - naphthyridines.

CONCLUSIONS

The Co catalyzed cooligomerization of the tetrahydroisoquinoline diynes of the type **4** with monoalkynes and nitriles provides a novel synthetic entry into the protoberberine nucleus with extensive ring D variation, including control of its substitution pattern and the incorporation of N atoms. Si in the form of the trimethylsilyl group, performs the useful function of an auxiliary group preventing autocyclization of the monoacetylenes, dictating regiochemistry, and serving as a potential leaving group when exposed to electrophiles.

EXPERIMENTAL

^{1}H NMR spectra were taken on a Varian T-60 (60 MHz), Varian EM-390 (90 MHz) or on home-built 200, 220 and 250 MHz instruments. Spectra are reported in δ referenced to TMS where CCl_4 was the solvent. When other solvents were used, peaks were measured relative to their residual proton peak using the following chemical shifts: $CDCl_3$ δ 7.24, C_6D_6 7.15. ^{13}C NMR spectra were measured at 25.14 MHz with a Nicolet TT-23 spectrometer. Chemical shifts are expressed downfield from internal TMS, referenced to the central peak of the $CDCl_3$ triplet (77.0 ppm downfield from TMS). IR spectra were observed on a Perkin–Elmer 337 spectrometer or Perkin–Elmer 681 spectrometer, and are reported in cm^{-1}. Mass spectra and elemental analyses were performed by the Mass Spectral Service and Microanalytical Laboratory of the University of California, Berkeley, California. Analyses are within 0.3% of calculated values unless otherwise noted. M.ps and b.ps are uncorrected. M.ps were determined on a Thomas–Hoover Unimelt apparatus. Column chromatography was carried out using Alfa aluminum oxide, activated, neutral, CAMAG, 95+%, −60 mesh to which 6% water was added (activity III), or EM reagents silica gel 60, 70–230 mesh ASTM. Preparative tlc was performed on plates prepared from EM reagents silica gel PF-254 with $CaSO_4 \cdot 1/2H_2O$ using a spinning plate, continuous elution system (Chromatotron, Harrison Research) under N_2. Anhyd ether was used as received. THF was distilled from Na-benzophenone. Diisopropylamine was distilled under N_2 from KOH pellets and used immediately. All reactions were conducted under N_2.

3,4-Dihydroisoquinoline (**3a**). A mixture of 1,2,3,4-tetrahydroisoquinoline (5.4 g, 40.6 mmol) and N-chlorosuccinimide (9.43 g, 70.7 mmol) in ether (150 mL) was stirred at room temp for 0.5 hr, then filtered. The filtrate was washed with ether, extracted with water and brine, then dried ($MgSO_4$).

After filtration, the soln was concentrated by rotary evaporation to a volume of *ca* 20 mL, then added slowly (0.5 hr) to a stirred soln of EtOH containing KOH (2.67 g of 85% KOH, 40.5 mmol). The internal temp of this alcoholic soln was kept between 5° and 10° during the addition with an ice bath. After the addition was complete, the soln was stirred at room temp for 12 hr.

Ether (40 mL) was then added and the soln was dried ($MgSO_4$). Filtration, concentration, then distillation (b.p. 37°; 0.005 T) gave **3a** (5.23 g, 39.9 mmol, 98%) which solidified upon standing as colorless crystals: m.p. 49–50°: ^{1}H NMR (60 MHz, CCl_4) δ 8.12 (t, J = 2, 1H), 7.17 (m, 4H), 3.67 (m, 2H), 2.67 (br t, J = 8, 2H); IR (neat, before crystallization) 2900, 1615, 1205, 998, 875, 750; *m/e* (rel intensity) 131 (M^+, 100), 129 (12), 104 (49), 103 (48), 102 (27), 77 (53).

2-(3,4-Dimethoxyphenyl)ethylformamide (**2b**). A soln of homoveratrylamine (10 g, 0.055 mol) and freshly distilled methyl formate (33.1 g, 0.551 mol) was stirred at room temp for 12 hr. Removal of MeOH and methyl formate by vacuum transfer gave **2b** (11.53 g, 0.055 mol, 100%): viscous, colorless oil; ^{1}H NMR (200 MHz, $CDCl_3$) δ 8.10 (d, J = 1.33, 1H), 6.70 (m, 3H), 5.62 (br s, 1H), 3.84 (s, 3H), 3.83 (s, 3H), 3.52 (dt, J = 6.9, 6.9, 2H), 2.76 (t, J = 6.9, 2H).

1 - (3 - Trimethylsilyl - 2 - propynyl) - 1,2,3,4 - tetrahydroisoquinoline. To Mg turnings (0.28 g, 10 mmol) and 40 mL abs ether in a 100 mL round bottom flask equipped with a reflux condenser and magnetic stirring bar was added 10 mL of an ether soln containing 3 - bromo - 1 - trimethylsilylpropyne[8] (1.60 g, 8.38 mmol). This mixture began spontaneous reflux within 1 or 2 min and was cooled with an ice bath as necessary to maintain gentle boiling. When vigorous reaction had subsided, the soln was left to stir at room temp for 1 hr. The Grignard reagent was then transferred via cannula to a 100 mL round bottom flask containing 3,4-dihydroisoquinoline (1.10 g, 8.38 mmol). After 1 or 2 min, when the initially vigorous reaction had subsided, the ice bath was removed and the soln was left to stir at room temp. After 3.75 hr, when the reaction had shown no visible change by GLC for over an hour, water was carefully added to quench any remaining Grignard reagent. The ether layer was separated and washed with water and brine, then dried over Na_2SO_4. Filtration and concentration by rotary evaporation gave 2.31 g of a light yellow oil. Sublimation (room temp, 0.005 T) for 20 hr afforded 1,6 - bis - (trimethylsilyl) - 1,5 - hexadiyne as colorless crystals (m.p. 47°, spectrally identical to an authentic sample).[10]

The remaining material was extracted into 75 mL of 5% aqueous AcOH, washed with ether and then neutralized by the slow addition of NaOH pellets. The ether layer was separated, washed with water and brine, then dried over Na_2SO_4. Filtration and evaporation of solvent gave the desired product (940 mg, 3.87 mmol, 46%): pale yellow oil; ^{1}H NMR (60 MHz, CCl_4) δ 6.95 (s, 4H), 4.07 (t, J = 6, 1H), 3.07 (m, 2H), 2.67 (m, 4H), 2.07 (br s, 1H); IR (neat) 3300, 2995, 2815, 2195, 1495, 1450, 1430, 1315,

1255, 1080; *m/e* (rel intensity) 243 (M^+, 0.17), 228 (2.7), 132 (100), 130 (19), 73 (11). The hydrobromide of 1 - (3 - trimethylsilyl - 2 - propynyl) - 1,2,3,4 - tetrahydroisoquinoline is isolated during the preparation of **4a** (*vide infra*) as analytically pure colorless crystals (m.p. 168–169°).

1 - (3 - *Trimethylsilyl* - 2 - *propynyl*) - 2 - (2 - *propynyl*) - 1,2,3,4 - *tetrahydroisoquinoline* (**4a**). Propargyl bromide (113 μL, 179 mg, 1.5 mmol) was added via syringe to a soln of 1 - (3 - trimethylsilyl - 2 - propynyl) - 1,2,3,4 - tetrahydroisoquinoline (733 mg, 3.01 mmol). After heating to reflux for 2 hr, the soln was cooled, then concentrated under high vacuum to give a red, oily residue.

Crystallization from CCl_4 yielded the hydrobromide salt of 1 - (3 - trimethylsilyl - 2 - propynyl) - 1,2,3,4 - tetrahydroisoquinoline [215 mg, 0.664 mmol, 22% based on 1 - (3 - trimethylsilyl - 2 - propynyl) - 1,2,3,4 - tetrahydroisoquinoline]: white crystals, m.p. 168–169° (from CCl_4); ^{1}H NMR (90 MHz, $CDCl_3$) δ 7.30 (m, 4H), 4.77 (t, J = 6, 1H), 3.68 (sex, J = 2.5, 2H), 3.20 (m, 4H), 0.08 (s, 9H); Anal. ($C_{15}H_{22}BrNSi$) C, H, N, Br.

The supernatant was purified by ptlc on silica eluting with $CHCl_3$/MeOH/conc NH_4OH aq (97:3:1) to afford **4a** (280 mg, 0.996 mmol, 66%): colorless oil; ^{1}H NMR (60 MHz, CCl_4) δ 6.93 (m, 4H), 3.97 (t, J = 6, 1H), 3.53 (q, J = 2.5, 2H), 2.82 (m, 4H), 2.50 (d, J = 5, 2H), 2.03 (t, J = 3, 1H), 0.12 (s, 9H); IR (neat) 3275, 2900, 2810, 2180, 1495, 1450, 1435, 1325, 1250, 1135, 1100, 1080; *m/e* (rel intensity) 281 (M^+, 0.6), 266 (14), 242 (3), 241 (13), 171 (100), 170 (64), 169 (29), 131 (32), 97 (12); HRMS Calc. ($C_{17}H_{20}NSi$, for M^+–CH_3): 266.1365. Found: 266.1366.

6,7 - *Dimethoxy* - 1 - (3 - *trimethylsilyl* - 2 - *propynyl*) - 2 - (2 - *propynyl*) - 1,2,3,4 - *tetrahydroisoquinoline* (**4b**). A soln of 1-trimethylsilylpropynyl bromide[8] (6.55 g, 0.034 mol) in 25 mL abs ether was added via syringe pump over 1 hr to rapidly stirred Mg turnings (9.27 g, 0.382 mol) in 65 mL abs ether at 0°. The mixture was stirred for 1 hr at 0°, then transferred via cannula into a soln of 6,7 - dimethoxy - 3,4 - dihydroisoquinoline[7] (3.275 g, 0.171 mol) in 75 mL dry THF at 0°. After the soln was stirred at 0° for 1 hr, propargyl bromide (4.89 g of a soln in 20% toluene, 0.034 mol) in 5 mL THF was added, followed by hexamethylphosphoramide (5.01 g, 0.028 mol). The soln was warmed to room temp and then heated to reflux for 1 hr. After the addition of 25 mL ice water, the organic material was taken up in CH_2Cl_2, washed with brine and sat $NaHCO_3$ aq, then dried ($MgSO_4$). Concentration, then filtration (SiO_2; $CHCl_3$: petroleum ether, 4:1) gave 4.20 g of a light yellow oil. Crystallization gave **4b** (3.92 g, 0.011 mol, 67%): colorless crystals, m.p. 80–80.5° (from hexane); ^{1}H NMR (250 MHz, $CDCl_3$) δ 6.81 (s, 1H), 6.54 (s, 1H), 4.01 (dd, J = 5.6, 5.6, 1H), 3.83 (s, 3H), 3.82 (s, 3H), 3.69 (dd, J = 2.4, 16.9, 1H), 3.50 (dd, J = 2.4, 16.9, 1H), 2.96 (m, 2H), 2.72 (dd, J = 5.6, 5.6, 2H), 2.61 (m, 2H), 2.20 (dd, J = 2.4, 2.4, 1H), 0.09 (s, 9H); IR (KBr) 3270, 3050, 2940, 2910, 2860, 2170, 1610, 1520, 1250, 1237, 1140, 1100, 848; *m/e* (rel intensity) 341 (M^+, 0.53), 326 (2), 301 (17), 230 (100), 214 (9), 176 (14), 73 (11); Anal. ($C_{20}H_{27}NO_2Si$) C, H, N.

1,2 - *Bis*(2 - *propynyl*) - 1,2,3,4 - *tetrahydroisoquinoline* (**5a**). Compound **4a** (260 mg, 0.92 mmol) was dissolved in 20 mL of a 1% soln of KOH in abs EtOH. After stirring at room temp for 2.5 hr, this soln was diluted to 50 mL with water and extracted with ether.

The combined ether layers were washed with brine and dried over Na_2SO_4. Concentration on the rotary evaporator and complete solvent removal under high vacuum produced **5a** as a pale yellow crystalline solid (193 mg, 100%). Ptlc of this material on silica gel eluting with $CHCl_3$/MeOH/conc NH_4OH aq (in a volume ratio of 97:3:1) yielded **5a** (174 mg, 0.832 mmol, 91%): colorless crystals, m.p. 84–85°; analytically pure material obtained by sublimation at 45°/0.001 T): ^{1}H NMR (90 MHz, CCl_4) δ 6.98 (m, 4H), 3.97 (t, J = 5, 1H), 3.55 (quin, J = 3, 2H), 2.87 (m, 4H), 2.53 (quin, J = 3, 2H), 2.05 (t, J = 2, 1H), 1.78 (t, J = 2, 1H); IR (KBr) 3225, 2930, 2800, 2180, 2100, 1380, 1340, 1310, 1130, 1085, 1055, 1040, 1005, 975, 950, 900; *m/e* (rel intensity), M^+ not observed, 171 (49), 170 (100), 168 (12), 146 (13), 132 (27), 131 (16), 130 (68), 103 (33), 77 (32), 39 (50). Anal. ($C_{15}H_{15}N$)C, H, N.

6,7 - *Dimethoxy* - 1,2 - *bis*(2 - *propynyl*) - 1,2,3,4 - *tetrahydroisoquinoline* (**5b**). A soln of **4b** (0.50 g, 1.47 mmol) in 35 mL of 1% KOH in abs EtOH was stirred at room temp for 5 hr. The mixture was diluted with 75 mL H_2O, extracted with CH_2Cl_2, washed with brine, then dried (Na_2SO_4). Concentration, then chromatography on SiO_2 (ether: pet ether, 2:1) gave **5b** (0.394 g, 1.47 mmol, 100%): colorless oil; ^{1}H NMR (250 MHz, $CDCl_3$) δ 6.67 (s, 1H), 6.46 (s, 1H), 3.93 (dd, J = 5.4, 5.4, 1H), 3.73 (s, 3H), 3.72 (s, 3H), 3.59 (dd, J = 2.3, 17, 1H), 3.42 (dd, J = 2.3, 17, 1H), 2.95 (ddd, J = 6, 6, 12, 1H), 2.88 (ddd, J = 6, 6, 12, 1H), 2.65 (m, 2H), 2.58 (ddd, J = 2.5, 8.5, 15.7, 1H), 2.48 (ddd, J = 2.5, 8.5, 15.7, 1H), 2.12 (dd, J = 2.3, 2.3, 1H), 1.90 (dd, J = 2.6, 2.6, 1H); IR (CCl_4) 3330, 2940, 2120, 1680, 1610, 1500, 1435, 1020, 855; *m/e* (rel intensity) 269 (M^+, 0.1), 230, (100), 214 (18), 191 (12), 176 (72); HRMS Calc. ($C_{17}H_{19}NO_2$): 269.1402. Found: 269.1403.

5,6,13,13a - *Tetrahydro* - 10,11 - *bis*(*trimethylsilyl*) - 8H - *dibenzo* [*a, g*] *quinolizine* (**6a**). A soln of **5a** (135 mg, 0.65 mmol), bis(trimethylsilyl)ethyne (7 mL), n-octane (1.5 mL) and $CpCo(CO)_2$ (25 μL) was added via syringe pump over 87 hr to a refluxing soln of 7 mL bis(trimethylsilyl)ethyne containing 25 μL $CpCo(CO)_2$.

After the addition was complete, the mixture was left at reflux for an additional 8 hr. The soln was then cooled to room temp and volatile materials were removed by vacuum transfer. The residue, a dark brown oil, was chromatographed [ptlc on silica gel eluting twice with ether/petroleum ether (15:85)] to give **6a** (212 mg, 0.559 mmol, 87%): pale yellow crystals, m.p. 42–43° (from petroleum ether at −78°); ^{1}H NMR (60 MHz, CCl_4/$CDCl_3$, 1:1) δ 7.38 (s, 1H), 7.30 (s, 1H), 7.15 (m, 4H), 3.83 (d, J = 7, 2H), 3.52 (t, J = 5, 1H), 2.92 (m, 6H), 0.35 (s, 18H); IR ($CHCl_3$) 3050, 2830, 2790, 1740, 1650, 1490, 1360, 1245, 1140, 1125, 1100, 1015, 985, 955; *m/e* (rel intensity) 379 (M^+, 37), 378 (22), 248 (24), 233 (13), 159 (11), 132 (6), 130 (23), 73 (100); analytically pure material was obtained by sublimation at 95°/0.001 T; Anal. ($C_{23}H_{33}NSi_2$) C, H, N.

5,6,13,13a - *Tetrahydro* - 2,3 - *dimethoxy* - 10,11 - *bis*(*trimethylsilyl*) - 8H - *dibenzo*[*a, g*]*quinolizine* (**6b**)

Compound **5b** (175 mg, 0.65 mmol) was dissolved in 19 mL bis(trimethylsilyl)ethyne, toluene, and glyme (volume ratio 12:6:1) containing 30 μL of $CpCo(CO)_2$, and added over 4.5 d to bis(trimethylsilyl)ethyne (15 mL) containing added $CpCo(CO)_2$ (30 μL). Ptlc on silica gel eluting with 4% MeOH in $CHCl_3$ gave, after developing the plate twice, the desired product as a viscous golden yellow oil (285 mg, 98%). Microdistillation at 90°/2 × 10^{-3} T afforded **6b** (265 mg, 0.604 mmol, 93%): ^{1}H NMR (220 MHz, $CDCl_3$) δ 7.52 (s, 1H), 7.43 (s, 1H), 6.77 (s, 1H), 6.63 (s, 1H), 3.93 (s, 3H), 3.88 (s, 3H), 3.69 (m, 1H), 3.20 (m, 4H), 2.69 (m, 4H), 0.47 (s, 9H), 0.45 (s, 9H); IR (neat) 3000, 2750, 1740, 1575, 1460, 1370, 1250, 1120, 1020, 955, 840; *m/e* (rel intensity) 440 (M^+, 37), 439 (100), 424 (23), 249 (14), 248 (17), 233 (11), 203 (18), 191 (18), 190 (76), 161 (13), 159 (13), 149 (19), 111 (10), 73 (83); HRMS Calc. ($C_{25}H_{37}NO_2Si_2$): 439.2364. Found: 439.2362.

5,6,13,13a - *Tetrahydro* - 2,3,11 - *trimethoxy* - 10 - *trimethylsilyl* - 8H - *dibenzo*[*a, g*]*quinolizine* (**6d**) and 5,6,13,13a - *tetrahydro* - 2,3,10 - *trimethoxy* - 11 - *trimethylsilyl* - 8H - *dibenzo*[*a, g*]*quinolizine* (**6e**). A soln of **5b** (0.60 g, 2.23 mmol), trimethylsilylmethoxyethyne[4b] (0.571 g, 4.46 mmol), and $CpCo(CO)_2$ (0.401 g, 2.30 mmol) in 15 mL of deoxygenated *m*-xylene was added via syringe pump over a period of 6 hr to 50 mL of refluxing, deoxygenated *m*-xylene while irradiating with a 250 W GE-ENH slide projector lamp. After the mixture was heated to reflux for an additional 2 hr, the soln was cooled to room temp and the volatiles were removed by vacuum transfer. The black oil was filtered through SiO_2(CH_2Cl_2), then purified by flash chromatography[13] (pet ether: EtOAc, 1.5:1) to give a 1:1 ratio of **6d** and **6e**: **6d** (0.301 g, 0.758 mmol, 34%): pale yellow oil; ^{1}H NMR (250 MHz, C_6D_6) δ 7.22 (s, 1H), 6.72 (s, 1H), 6.48 (s, 1H), 6.40 (s, 1H), 3.89 (d, J = 5.2, 1H), 3.59 (m, 2H), 3.55 (s, 3H), 3.45 (s, 3H), 3.36 (s, 3H), 3.25–2.93 (m, 4H), 2.50 (m, 2H), 0.47 (s, 9H); IR ($CHCl_3$) 3040, 2980, 2850, 2790, 1750, 1610, 1525, 1240, 1140, 850; *m/e* (rel intensity) 397 (M^+, 62), 382 (17), 206 (100), 161 (81), 117 (18), 95 (15), 71 (31), 57 (47); HRMS Calc. ($C_{23}H_{31}NO_3Si$): 397.2073. Found: 397.2068. (Found: C, 68.96; H, 7.90; N, 3.12. Calc. ($C_{23}H_{31}NO_3Si$): C, 69.48; H, 7.86; N, 3.52%). **6e** (0.301 g, 0.758 mmol, 34%): pale yellow oil; ^{1}H NMR (250 MHz, C_6D_6) δ 7.31 (s, 1H), 6.70 (s, 1H), 6.47 (s, 1H), 6.34 (s, 1H), 3.87 (d, J = 6, 1H), 3.59 (m, 2H), 3.50 (s, 3H), 3.46 (s, 3H),

3.37 (s, 3H), 3.27–2.95 (m, 4H), 2.50 (m, 2H), 0.46 (s, 9H); IR ($CHCl_3$) 3030, 2980, 2860, 2780, 1740, 1610, 1520, 1220, 1110, 840; *m/e* (rel intensity) 397 (M^+, 51) 382 (12), 206 (100), 190 (40), 161 (80), 149 (14), 117 (21), 73 (20), 57 (17); HRMS Calc. ($C_{23}H_{31}NO_3Si$): 397.2073. Found: 397.2071. (Found: C, 68.78; H, 7.87; N, 3.40. Calc. ($C_{23}H_{31}NO_3Si$): C, 69.48; H, 7.86; N, 3.52%).

5,6,13,13a - *Tetrahydro* - 2,3,11 - *trimethoxy* - 8H - *dibenzo[a, g]* - *quinolizine* (**6f**). Trifluoroacetic acid (0.74 g, 6.49 mmol) in 0.5 mL CCl_4 was added to a soln of **6d** (0.060 g, 0.15 mmol) in 4.5 mL CCl_4 and the mixture was stirred for 1.5 hr. Workup (see **6g**) gave **6f** (0.049 g, 0.15 mmol, 100%): pale yellow oil; ^{1}H NMR (250 MHz, C_6D_6) δ 6.90 (d, J = 8.8, 1H), 6.77 (dd, J = 3.8, 8.8, 1H), 6.67 (br s, 2H), 6.47 (s, 1H), 3.84 (d, J = 17.5, 1H), 3.50 (s, 3H), 3.45 (m, 2H), 3.40 (s, 3H), 3.24 (s, 3H), 3.18 (m, 2H), 2.92 (m, 2H), 2.50 (m, 2H). Bubbling HCl gas through an ether soln of **6f** (0.030 g, 0.092 mmol) gave the hydrochloride: m.p. 200–203° (from EtOH); lit. 185–187°,[3] 195–198°[14] and 204–206°.[14]

5,6,13,13a - *Tetrahydro* - 2,3,10 - *trimethoxy* - 11,12 - *bis(trimethylsilyl)* - 8H - *dibenzo[a, g]quinolizine* (**7a**). This cyclization was carried out using the same conditions as in the cyclization of **5b** with trimethylsilylmethoxyethyne. Thus, the reaction of **4b** (0.500 g, 1.466 mmol), trimethylsilylmethoxyethyne (0.375 g, 2.932 mmol) and $CpCo(CO)_2$ (0.234 g, 1.466 mmol) gave after filtration (neutral alumina; CH_2Cl_2: petroleum ether, 3:1) then crystallization, compound **7a** (0.402, 0.856 mmol, 58%): colorless needles, m.p. 126–128° (from hexane); ^{1}H NMR (250 MHz, C_6D_6) δ 6.84 (s, 1H), 6.48 (s, 1H), 6.33 (s, 1H), 3.94 (d, J = 15, 1H), 3.58 (s, 3H), 3.46 (s, 3H), 3.39 (m, 2H), 3.35 (s, 3H), 3.18 (m, 2H), 2.90 (m, 2H), 2.40 (m, 2H), 0.55 (s, 9H), 0.44 (s, 9H); IR (CCl_4) 2990, 2940, 2900, 2810, 2800, 2750, 1570, 1545, 1510, 1380, 1260, 1140, 870, 775; *m/e* (rel intensity) 469 (M^+, 55), 454 (30), 278 (73), 263 (30), 233 (46), 190 (34), 89 (51), 73 (100), 57 (56); HRMS Calc. ($C_{26}H_{39}NO_3Si_2$): 469.2468. Found: 469.2453. (Found: C, 65.89; H, 8.37; N, 2.98. Calc. ($C_{26}H_{39}NO_3Si_2$): C, 66.47; H, 8.37; N, 2.98%).

5,6,13,13a - *Tetrahydro* - 2,3,10 - *trimethoxy* - 12 - *trimethylsilyl* - 8H - *dibenzo[a, g]quinolizine* (**7b**) and 5,6,13,13a - *tetrahydro* - 2,3,10 - *trimethoxy* - 8H - *dibenzo[a, g]* - *quinolizine* (**6g**). Trifluoroacetic acid (0.74 g, 6.49 mmol) in 1 mL CCl_4 was added via syringe to a stirred soln of **7a** (0.060 g, 0.128 mmol) in 4 mL CCl_4. The reaction was stirred for 12 hr and then taken up in ether. The red soln was washed with sat $NaHCO_3$ aq, brine and dried (Na_2SO_4). Concentration and chromatography (SiO_2, petroleum ether: acetone, 3:1) gave first **7b** (0.038 g, 0.096 mmol, 75%): colorless oil; ^{1}H NMR (250 MHz, C_6D_6) δ 7.20 (d, J = 2.3, 1H), 6.84 (s, 1H), 6.59 (d, J = 2.3, 1H), 6.49 (s, 1H), 3.87 (d, J = 15, 1H), 3.70 (s, 3H), 3.58 (m, 2H), 3.46 (s, 6H), 3.15 (m, 2H), 2.95 (m, 2H), 2.46 (m, 2H), 0.26 (s, 9H); IR (CCl_4) 3000, 2960, 2945, 2860, 2830, 2760, 1610, 1515, 1460, 1260, 1110, 1060, 1010, 840; *m/e* (rel intensity) 397 (M^+, 86), 382 (14), 206 (100), 191 (81), 177 (15), 99 (9), 73 (8); HRMS Calc. ($C_{23}H_{31}NO_3Si$): 397.2073. Found: 397.2082. **6g** (0.010 g, 0.030 mmol, 24%): colorless oil; ^{1}H NMR (C_6D_6) δ 6.95 (d, J = 7.5, 1H), 6.75 (dd, J = 2.5, 7.5, 1H), 6.65 (s, 1H), 6.60 (d, J = 2.5, 1H), 6.42 (s, 1H), 3.8 (d, J = 17, 1H), 3.54 (m, 2H), 3.50 (s, 3H), 3.45 (s, 3H), 3.39 (s, 3H), 3.15 (m, 2H), 2.90 (m, 2H), 2.45 (m, 2H); *m/e* (rel intensity) 325 (M^+, 40), 190 (14), 164 (100), 149 (39), 134 (59), 57 (45). Bubbling HCl gas through an ether soln of **6g** (0.015 mg, 0.046 mmol) gave the hydrochloride derivative as yellow needles, m.p. 220–223°, from EtOH, (lit.[15] 226–227°). Compound **6g** was identical to the product formed in the protodesilylation of **6e** (see procedure for **6f**); HCl derivative: m.p. 224–225° (from MeOH).

Chloroacetaldehyde dineopentyl acetal. A soln of neopentyl alcohol (100.0 g, 1.134 mol), chloroacetaldehyde dimethyl acetal (28.13 g, 0.227 mol), and 12N HCl (1 mL) was heated until the theoretical quantity of MeOH (18.35 mL) had been distilled. Distillation gave chloroacetaldehyde dineopentyl acetal (49.0 g, 0.207 mol, 92%): colorless liquid, b.p. 100–103°, 12 T; ^{1}H NMR (90 MHz, CCl_4) δ 4.45 (t, J = 6, 1H), 3.35 (d, J = 6, 2H), 3.20 (d, J = 7, 2H), 3.00 (d, J = 7, 2H), 0.90 (s, 18H); IR (neat) 2980, 2940, 2875, 1470, 1360, 1150, 1075; *m/e* (rel intensity) molecular ion not observed, 187 (1), 151 (14), 149 (43), 72 (16), 71 (100), 70 (7), 57 (12); ^{13}C NMR ($CDCl_3$) δ 102.5, 76.9, 43.6, 31.8, 26.5; Anal. ($C_{12}H_{25}ClO_2$) C, H, Cl.

Trimethylsilylneopentoxyethyne. BuLi (135.57 mL, 0.203 mol, 1.5 M in hexane) was added via syringe to a stirred soln of diisopropylamine (20.58 g, 0.203 mol) in 200 mL dry ether at 0°. The soln was warmed to room temp, then chloroacetaldehyde dineopentyl acetal (15 g, 0.064 mol) was added over a period of 20 min. The mixture was refluxed for 20 hr, then cooled in an ice bath. After the addition of trimethylsilyl chloride (22.086 g, 0.203 mol), the soln was heated to reflux for 24 hr and cooled to 0°, then 125 mL H_2O was added. The aqueous layer was separated and extracted with ether. The combined organic extracts were washed with brine and sat $NaHCO_3$ aq, then dried over K_2CO_3. Rotary evaporation of the solvent and distillation gave trimethylsilylneopentoxyethyne (9.84 g, 0.053 mol, 84%): colorless liquid, b.p. 73–78°, 11 T; ^{1}H NMR (90 MHz, CCl_4) δ 3.70 (s, 2H), 0.95 (s, 9H), 0.11 (s, 9H); IR (neat) 2990, 2900, 2180, 1245, 840; *m/e* (rel intensity) 184 (M^+, 2), 182 (9), 115 (15), 99 (88), 71 (88), 55 (35), 43 (100); ^{13}C NMR ($CDCl_3$) δ 110.9, 89.1, 35.3, 32.3, 25.8, 0.6. Anal. ($C_{10}H_{20}OSi$)C, H.

5,6,13,13a - *Tetrahydro* - 2,3 - *dimethoxy* - 10 - *neopentoxy* - 11,12 - *bis(trimethylsilyl)* - 8H - *dibenzo[a, g]quinolizine* (**7c**). This cyclization was carried out using the same conditions as in the cyclization of **5b** with trimethylsilylmethoxyethyne. Thus, the reaction of **4b** (0.600 g, 1.759 mmol), trimethylsilylneopentoxyethyne (0.648 g, 3.519 mmol) and $CpCo(CO)_2$ (0.316 g, 1.759 mmol) gave after filtration (SiO_2; CH_2Cl_2:acetone, 3:1) then crystallization, compound **7c** (0.563 g, 1.07 mmol, 61%): colorless crystals, m.p. 194–195° (sinter), 200–201° (dec) (from petroleum ether); ^{1}H NMR (250 MHz, $CDCl_3$) δ 6.73 (s, 1H), 6.61 (s, 1H), 6.47 (s, 1H), 4.03 (d, J = 15, 1H), 3.86 (s, 8H), 3.60 (m, 4H), 3.12 (m, 2H), 2.60 (m, 2H), 1.06 (s, 9H), 0.39 (s, 9H), 0.33 (s, 9H); IR ($CHCl_3$) 3050, 2950, 2900, 2840, 2760, 1620, 1510, 1380, 1280, 1140, 860; *m/e* (rel intensity) 525 (M^+, 46), 510 (11), 452 (12), 334 (53), 248 (52), 192 (36), 169 (28), 73 (72), 43 (100). (Found: C, 67.93; H, 8.76; N, 2.84. Calc. ($C_{30}H_{47}NO_2Si_2$): C, 68.52; H, 8.95; N, 2.67%).

5,6,13,13a - *Tetrahydro* - 2,3 - *dimethoxy* - 10 - *neopentoxy* - 12 - *trimethylsilyl* - 8H - *dibenzo[a, g]quinolizine* (**7d**). Trifluoroacetic acid (1.487 g, 13.04 mmol) in 1 mL CCl_4 was added to a soln of **7c** (0.137 g, 0.261 mmol) in 9 mL CCl_4. After stirring for 45 min, the mixture was worked up in the usual manner (see **6g**). Chromatography (SiO_2, CH_2Cl_2) gave **7d** (0.117 g, 0.259 mmol, 99%): yellow oil; ^{1}H NMR (250 MHz, C_6D_6) δ 7.25 (d, J = 2.5, 1H), 6.83 (s, 1H), 6.64 (d, J = 2.5, 1H), 6.48 (s, 1H), 4.02 (d, J = 15, 1H), 3.68 (m, 2H), 3.57 (s, 3H), 3.53 (s, 2H), 3.47 (s, 3H), 3.25 (m, 2H), 3.08 (m, 2H), 2.58 (m, 2H), 1.03 (s, 9H), 0.27 (s, 9H); IR (CH_2Cl_2) 2960, 2880, 2810, 2760, 1640, 1595, 1510, 1260, 1130, 1120, 840; *m/e* (rel intensity) 453 (M^+, 55), 438 (10), 380 (14), 262 (58), 220 (14), 192 (83), 177 (67), 71 (50), 43 (100); HRMS Calc. ($C_{27}H_{39}NO_3Si$): 453.2699. Found: 453.2692.

5,6,13,13a - *Tetrahydro* - 2,3 - *dimethoxy* - 11 - n - *butyl* - 12 - *trimethylsilyl* - 8H - *dibenzo[a, g]quinolizine* (**7e**) and 5,6,13,13a - *tetrahydro* - 2,3 - *dimethoxy* - 10 - n - *butyl* - 12 - *trimethylsilyl* - 8H - *dibenzo[a, g]quinolizine* (**7f**). A soln of **4b** (0.100 g, 0.293 mmol), 1-hexyne (0.024 g, 0.293 mmol) and 15 μL $CpCo(CO)_2$ in 10 mL deoxygenated *m*-xylene was added via syringe pump over a period of 6 hr to 30 mL of refluxing deoxygenated *m*-xylene and 15 μL of $CpCo(CO)_2$ while irradiating with a 250 W GE-ENH slide projector lamp. After the mixture was refluxed an additional 4 hr, the soln was cooled to room temp and the solvent was removed by vacuum transfer. The black oil was filtered through SiO_2 (CH_2Cl_2), and the desired isomers **7e** and **7f** were purified and separated by ptlc (CH_2Cl_2:acetone, 10:1) to give **7e** (0.003 g, 0.007 mmol, 2.5%): pale yellow oil; ^{1}H NMR (250 MHz, C_6D_6) δ 7.03 (d, J = 8, 1H), 6.96 (d, J = 8, 1H), 6.80 (s, 1H), 6.48 (s, 1H), 3.94 (d, J = 17.5, 1H), 3.62 (m, 2H), 3.58 (s, 3H), 3.44 (s, 3H), 3.18 (m, 2H), 2.95 (m, 1H), 2.75 (m, 1H), 2.43 (m, 2H), 1.62 (m, 2H), 1.35 (m, 4H), 0.94 (br t, J = 10, 3H), 0.38 (s, 9H); IR (CCl_4) 2975, 2950, 2875, 2840, 2760, 1515, 1460, 1260, 1100, 1020, 850; *m/e* (rel intensity) 423 (M^+, 51), 408 (15), 348 (30), 232 (55), 190 (78), 175 (37), 73 (100); HRMS Calc. ($C_{26}H_{37}NO_2Si$): 423.2593. Found: 423.2588; and **7f** (0.003 g, 0.007 mmol, 2.5%): colorless oil; ^{1}H NMR (250 MHz, C_6D_6) δ 7.38 (d, J = 1.24, 1H), 6.88 (d, J = 1.24, 1H), 6.85 (s, 1H), 6.48 (s, 1H), 3.95 (d, J = 17.5, 1H), 3.63 (m, 2H), 3.56 (s, 3H), 3.46 (s, 3H), 3.20

(m, 1H), 2.96 (m, 1H), 2.58 (m, 2H), 2.45 (m, 2H), 1.63 (m, 2H), 1.35 (m, 4H), 0.92 (br t, J = 10, 3H), 0.33 (s, 9H); IR (CCl_4) 2975, 2950, 2865, 2750, 1520, 1450, 1260, 1100, 1020, 840; *m/e* (rel intensity) 423 (M^+, 67), 408 (20), 350 (14), 232 (33), 217 (67), 190 (100), 73 (55); HRMS Calc. ($C_{26}H_{37}NO_2Si$): 423.2593. Found: 423.2576.

5,6,13,13a - *Tetrahydro* - 2,3 - *dimethoxy* - 10 - *phenyl* - 12 - *trimethylsilyl* - 8H - *isoquino*[2,1-*b*]2,6 - *naphthyridine* (**8a**) and 5,6,13,13a - *tetrahydro* - 2,3 - *dimethoxy* - 10 - *phenyl* - 8H - *isoquino*[2,1-*b*]2,6 - *naphthyridine* (**8b**). The $CpCo(CO)_2$ (30 μL) catalyzed cocyclization of **4b** (0.200 g, 0.587 mmol) with benzonitrile (0.120 g, 1.173 mmol) was run under the same cyclization conditions as those used for **7e** and **7f**. Filtration through SiO_2 (CH_2Cl_2) gave crude **8a** (0.209 g, 0.469 mmol, 81%): yellow oil; ^{1}H NMR (250 MHz, $CDCl_3$) δ 8.08 (s, 1H), 8.06 (s, 1H), 7.41 (m, 3H), 7.36 (s, 1H), 6.74 (s, 1H), 6.63 (s, 1H), 4.10 (d, J = 16, 1H), 3.89 (s, 3H), 3.87 (s, 3H), 3.73 (m, 2H), 3.56 (m, 2H), 3.16 (m, 2H), 2.76 (m, 2H), 0.45 (s, 9H). Purification (4 mm SiO_2 spinning tlc plate; CH_2Cl_2: CH_3CN, 1:1) gave the protodesilylated product **8b** (0.162 g, 0.435 mmol, 74%): pale yellow oil; ^{1}H NMR (250 MHz, $CDCl_3$) δ 8.47 (s, 1H), 7.94 (s, 1H) 7.91 (s, 1H), 7.42 (m, 3H), 7.36 (s, 1H), 6.72 (s, 1H), 6.59 (s, 1H), 4.03 (d, J = 16, 1H), 3.87 (s, 3H), 3.84 (s, 3H), 3.65 (m, 2H), 3.37 (m, 1H), 3.10 (m, 2H), 2.82 (m, 1H), 2.60 (m, 2H); IR ($CHCl_3$) 3050, 3000, 2950, 2840, 2750, 1600, 1520, 1240, 1140; *m/e* (rel intensity) 372 (M^+, 77), 371 (100), 353 (10), 190 (19), 181 (34), 57 (18); HRMS Calc. ($C_{24}H_{24}N_2O_2$): 372.1837. Found: 372.1825.

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