# Total Syntheses of Vincadifformine, 3-Oxovincadifformine, Pseudo- and 20-*epi*-Pseudovincadifformine, Tabersonine, and $\Delta^{18}$-Tabersonine through Radical Reactions and Heck Reactions

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The pentacyclic alkaloids vincadifformine (**9**), $\psi$-vincadifformine (**15**), and *epi*-$\psi$-vincadifformine (**16**) could be synthesized by intramolecular free-radical-induced cyclizations of the tetracyclic intermediates **7**, **8**, and **18**, which were respectively obtained by condensation of the indoloazepine **1** with 2-(phenylselenyl)butyraldehyde and subsequent $N^b$-alkylation of the resulting tetracyclic amines **2** and **3**, or from condensation of (phenylselenyl)acetaldehyde with the alkylated indoloazepine **17**. The intermediates **2** and **3** also gave 3-oxovincadifformine (**21**) by an intermolecular radical alkylation with methyl acrylate. Their alkylation with (*Z*)-1,3-diiodopropene, phenyl selenoxide elimination, and intramolecular Heck reactions provided tabersonine (**24**) and 18,19-didehydrotabersonine (**27**).

In our previous studies, we have obtained high-yielding syntheses of a variety of vincadifformine and $\psi$-vincadifformine class alkaloids by exploitation of secodine-type cyclization reactions (intramolecular Diels−Alder reactions, Figure 1).[1,2] While the elaboration of diverse functionality in rings D and E of these products has been successful (e.g., resulting in the enantioselective syntheses of vindoline[3] and vinblastine[4−6]), we still faced a need for improvement in some late-stage functional group introductions as well as the consideration that a specific synthetic precursor for the intramolecular enamine/indoloacrylate reaction had to be generated for each alkaloid product.[5] It was therefore of interest to explore the syntheses of a few A,B,C,E-tetracyclic intermediates which might be converted into a variety of pentacyclic alkaloids by transformations that we had not yet utilized. Thus, we initiated a program of ring D annelations through radical and Heck-type cyclization reactions.

Condensation of α-(phenylselenyl)butyraldehyde[7] with the indoloazepine **1** (Scheme 1)[8] in refluxing toluene provided two tetracyclic amines, **2** (49%) and **3** (20%), with orientation of the amine function and the phenylselenyl substituent *cis* and *trans*, respectively. The relative configurations of these products were established by NOE NMR studies of the corresponding propargyl derivatives **4** and **5**, which showed an interaction between the propargyl and ethyl methylene hydrogens (8%) and the *o*-phenyl and C-17 and C-21 hydrogens (5%) for the $N^b$/Se *trans* isomer **5**.

The formation of two stereoisomers was expected as a consequence of the reaction of (*E*)- and (*Z*)-enamine isomers **6** in the intramolecular Diels−Alder reaction,

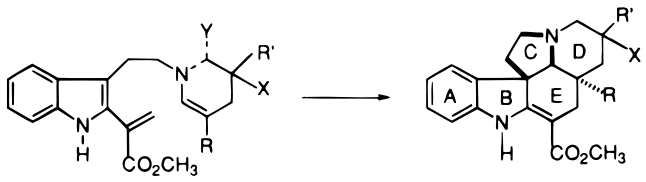


**Figure 1.**

favoring the $N^b$/Se *cis* isomer. That the relative amounts of the products are not the result of product equilibration during the reaction (see below) was shown by heating either pure tetracycle **2** or **3** in toluene, without formation of the corresponding epimer. However, when either pure epimer was heated in toluene with *p*-toluenesulfonic acid, a 1:2.5 equilibration ratio of the tetracyclic amines **2** and **3** resulted.

Alkylation of the tetracyclic amines **2** and **3** with 2,3-dibromopropene[9] furnished the corresponding tertiary amines **7** and **8**. The $N^b$/Se *trans* isomer **3** was alkylated much more rapidly than the *cis* isomer **2**. A reaction of either of the products **7** or **8** with 2.5 equiv of tri-*n*-butyltin hydride and a radical initiator (AIBN) then resulted in the formation of vincadifformine (**9**). The reducible (Br) substituent in the allylic amines **7** and **8** was required for this reaction to avoid the otherwise anticipated preferred cyclization to five-membered ring D products **10** and **11**. Indeed, these products were found in the cyclizations of the allylic amines **12** and **13**. Formation of a five-membered ring was also observed with the tetracyclic propargylic amines **4** and **5**, leading to the olefin **14**.

Stereochemical assignments to the methyl compounds **10** and **11** could be made from NOE NMR spectra, which showed interaction of the α-*N*-methine hydrogen at C-21 with the methyl group (17% by irradiation of $CH_3$, 3% by irradiation of methine H) or, respectively, with its α-methine hydrogen (13% and 17%). Hydrogenation of the olefin **14** gave only the minor cyclization product **11**.

In all of these radical cyclization reactions, the relative stereochemistry of the phenylselenyl substituent in the tetracyclic substrate had little, if any, influence on the product yield.

⊗ Abstract published in *Advance ACS Abstracts,* August 1, 1996.

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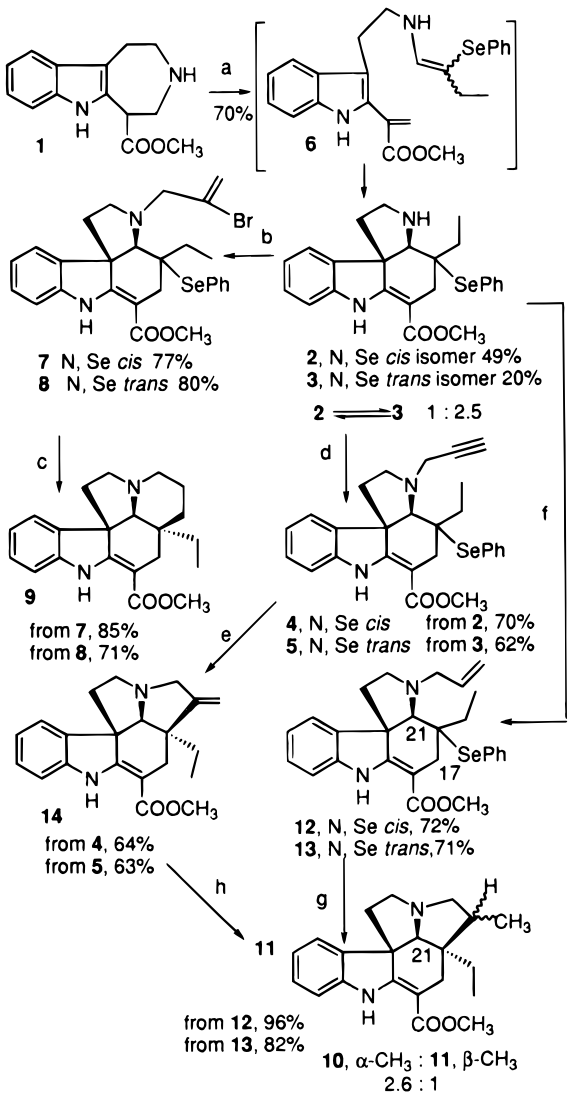
(9) Aldrich Chemical Co.

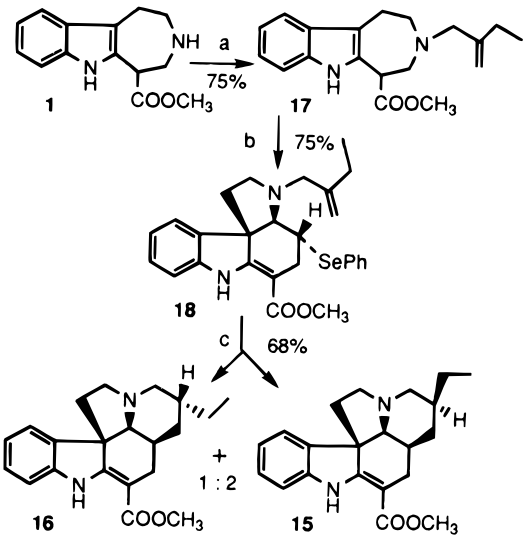
S0022-3263(96)00607-X CCC: $12.00 

**Scheme 1**[a]



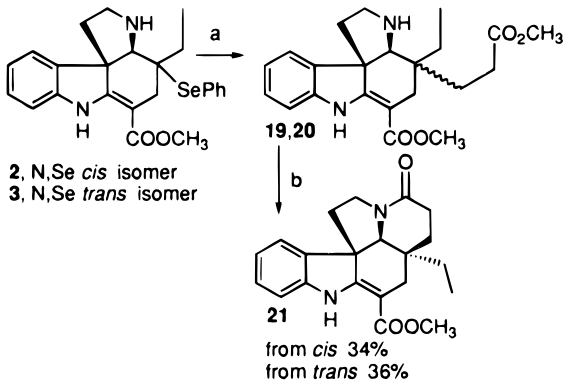

[a] Conditions: (a) $CH_3CH_2CH(SePH)CHO$, toluene, reflux, 18 h; (b) 2,3-dibromopropene, THF, 5 days; (c) 2.5 equiv of $Bu_3SnH$, AIBN, benzene, 85 °C, 2 h; (d) propargyl bromide, THF, 50 °C, 48 h; (e) $Bu_3SnH$, AIBN, benzene, 85 °C, 4 h; (f) allyl bromide, THF, 5 days; (g) 3 equiv of $Bu_3SnH$, AIBN, benzene, 85 °C, 12 h; (h) $H_2$/Pd.

**Scheme 2**[a]




[a] Conditions: (a) 2-ethyl-3-bromopropene, $K_2CO_3$, acetone; (b) $PhSeCH_2CHO$, toluene, reflux, 8 h; (c) $Bu_3SnH$/AIBN, syringe pump, 0.015 M in benzene, 85 °C.

**Scheme 3**[a]




[a] Conditions: (a) $Bu_3SnH$, AIBN, $CH_2{=}CHCOOCH_3$; (b) 1 equiv of *p*-TsOH, toluene, reflux, 18 h.

An analogous strategy could also be used for annelation of ring D in syntheses of $\psi$-vincadifformine (**15**) and 20-*epi*-$\psi$-vincadifformine (**16**, Scheme 2). Here, the indoloazepine **1** was first alkylated with 3-bromo-2-ethylpropene.[10] Condensation of the resulting tertiary amine **17** with (phenylselenyl)acetaldehyde[11] gave the tetracyclic phenylselenyl ether **18**. An (*E*)-enamine intermediate in the intramolecular Diels−Alder reaction step leads only to the $N^b$/Φ-Se *trans* product **18**, in analogy to formation and reaction of alkyl-substituted enamines.[12]

On slow addition of tri-*n*-butyltin hydride and AIBN to the phenylselenyl ether **18** in refluxing benzene, $\psi$-vincadifformine (**15**) and 20-*epi*-$\psi$-vincadifformine (**16**) were formed in a 2:1 ratio. The separate products did not epimerize under the reaction conditions, indicating a stereoselective hydrogen radical transfer to a pentacyclic C-20 radical intermediate.

In a variation of these ring D annelations, which is also based on a radical alkylation reaction, the tetracyclic phenylselenyl ethers **2** and **3** were treated with tri-*n*-butyltin hydride and AIBN and an excess of methyl acrylate (Scheme 3). The resulting mixture of epimeric esters **19** and **20,** on heating in the presence of acid, then provided 3-oxovincadifformine (**21**).[13] Once again, the $N^b$-H tetracycles **19** and **20** undergo epimerization.

To elaborate the phenylselenyl tetracyclic intermediates into more unsaturated congeners of vincadifformine, an alternative to the above radical cyclization strategy seemed more promising. Alkylation of the *cis*-$N^b$-phenylselenyl ether **2** with (*Z*)-1,3-diiodopropene[14] provided the (3-iodoallyl)amine **22** (Scheme 4). On oxidation of this selenyl ether **22** with *m*-chloroperoxybenzoic acid, followed by treatment with triphenylphosphine for *N*-oxide reduction, the tetracyclic conjugated diene **23** was formed. A reductive Heck reaction with palladium

(10) Prepared according to the published method: Corey, E. J.; Kirst, H. A.; Katzenellenbogen, J. A. *J. Am. Chem. Soc.* **1970**, *92*, 6314.
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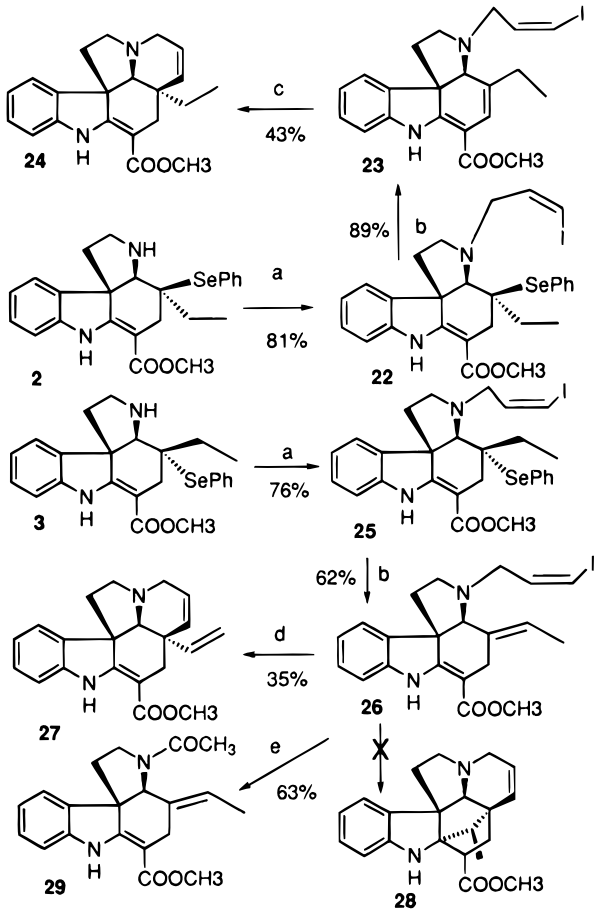
**Scheme 4**[a]




[a] Conditions: (a) (*Z*)-1,3-diiodopropene, $K_2CO_3$, THF, reflux, 6 h; (b) 2.2 equiv of *m*-CPBA, −75 °C, $CH_2Cl_2$; 2.2 equiv of $Ph_3P$, −30 °C; (c) $Pd(OAc)_2$, $Ph_3P$, HCOONa, $Et_3N/CH_3CN$, reflux, 12 h; (d) 0.4 equiv of $Pd(OAc)_2$, $Ph_3P$, $Et_3N/CH_3CN$, reflux, 3 h; (e) 1.5 equiv of $Pd(OAc)_2$, 3 equiv of $Ph_3P$, $CH_3CN$, reflux, 3 h.

acetate, triphenylphosphine, and sodium formate then resulted in cyclization to tabersonine **24**. No tabersonine was formed on treatment of the iodide **23** with tri-*n*-butyltin hydride and AIBN in refluxing benzene.

When the epimeric phenylselenyl ether **3** was subjected to the same reaction sequence, it was found that the selenoxide elimination derived from the *trans*-$N^b$-phenylselenyl intermediate **25** gave only the regiochemical alternative formation of the exocyclic olefin **26** (Scheme 4). The differing direction of selenoxide eliminations derived from the epimeric series **22** and **25** is a consequence of better $\beta$-allylic/$\pi$ orbital overlap in **22** *vs* $\alpha$-allylic/$\pi$ orbital overlap in **25**. There is also hindrance to achieving coplanarity of the $\alpha$-selenoxide and adjacent allylic hydrogen by the required torsion of an initial quasi-boat-like ring E selenoxide derived from **25**, because of increasing 1,3-quasi-diaxial repulsion of the ethyl and C-6 methylene groups in that process, thus favoring formation of the exocyclic double-bond product **26**.

Cyclization of the exocyclic olefin **26** by a nonreductive Heck reaction with palladium acetate, triphenylphosphine, and triethylamine provided $\Delta^{18}$-dehydrotabersonine (**27**). Unfortunately, a tandem double cyclization to vindolinine (**28**) could not be obtained using either catalytic or excess amounts of palladium acetate.[15]

The foregoing ring D annelation reactions expand the versatility of our biomimetic, secodine-type, intramolecular Diels−Alder approach to the aspidosperma and other vinca alkaloids. They also provide instructive novel examples demonstrating the compatibility of radical cyclizations and Heck reactions with basic amine and aminoacrylate functionalities.

## Experimental Section

**Methyl (±)-(3a*R**,4*S**,11b*R**)-and (±)-(3a*R**,4*R**,11b*R**)-2,3,3a,4,5,7-Hexahydro-4-ethyl-4-(phenylselenyl)-1*H*-pyrrolo[2,3-*d*]carbazole-6-carboxylate (2 and 3).** To a solution of 1.024 g (4.19 mmol) of the indoloazepine **1**,[8] dissolved in 70 mL of dry toluene at 60 °C, was added a solution of 2-(phenylselenyl)butyraldehyde[7] (0.955 g, 4.20 mmol) in 30 mL of dry toluene in one portion. The mixture was heated at reflux under argon for 18 h, until TLC showed that the reaction was complete. The reaction mixture was cooled, and the solvent was removed under reduced pressure to give a residue, which was purified by silica gel flash chromatography, eluting with 1:1 ethyl ether/pentane, to give 0.938 g (49.4%) of *cis* isomer **2** and 0.384 g (20.2%) of *trans* isomer **3**, both as white foams.

**For the less polar *cis* isomer 2:** mp 122−123 °C (ether/pentane 1:1); $R_f$ = 0.58 (1:1 ethyl acetate/hexane), 0.43 (1:1 ethyl ether/pentane); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 204, 222, 300, 332 nm; IR (thin film) $\nu_{max}$ 3374, 2962, 2928, 2882, 1676, 1609, 1437, 1284, 1247, 1201, 1103, 741 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 9.00 (br s, 1 H), 7.75 (dd, $J$ = 8.1, 1.4 Hz, 2 H), 7.35−7.27 (m, 3 H), 7.19 (d, $J$ = 7.5 Hz, 1 H), 7.14 (td, $J$ = 7.7, 1.2 Hz, 1 H), 6.86 (td, $J$ = 7.5, 1.0 Hz, 1 H), 6.81 (d, $J$ = 7.7 Hz, 1 H), 3.76 (s, 3 H), 3.39 (d, $J$ = 1.8 Hz, 1 H), 3.26−3.13 (m, 2 H), 2.81 (dd, $J$ = 15.1, 1.9 Hz, 1 H), 2.51 (d, $J$ = 15.1 Hz, 1 H), 2.02 (td, $J$ = 12, 6.8 Hz, 1 H), 1.88 (ddd, $J$ = 12, 2.5, 2.5 Hz, 1 H), 1.04−0.87 (m, 2 H), 0.79 (t, $J$ = 7.1 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 168.37, 166.70, 143.03, 137.39, 137.05, 128.85, 128.43, 127.96, 127.28, 121.85, 120.88, 109.36, 90.04, 68.27, 61.92, 57.30, 51.00, 45.49, 45.23, 27.89, 27.57, 8.58; MS *m*/*z* (relative intensity) 454 (2), 298 (3), 297 (16), 242 (7), 240 (9), 238 (8), 237 (11), 236 (4), 222 (4), 215 (8), 208 (8), 194 (8), 160 (10), 155 (7), 154 (15), 144 (7), 91 (12), 78 (8), 77 (10), 44 (100). Anal. Calcd for $C_{24}H_{26}N_2O_2Se$: C, 63.42; H, 5.77; N, 6.17. Found: C, 63.84; H, 5.89; N, 6.01.

**For the more polar *trans* isomer 3:** mp 140−145 °C (ether/pentane 1:1); $R_f$ = 0.26 (1:1 hexane/ethyl acetate), 0.20 (1:1 ethyl ether/pentane); CAS spray, yellow; UV (EtOH) $\lambda_{max}$ 204, 222, 298, 330 nm; IR (thin film) $\nu_{max}$ 3373, 2965, 2934, 2848, 1675, 1609, 1465, 1437, 1284, 1247, 1203, 742 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 9.15 (br s, 1 H), 7.27−7.29 (m, 3 H), 7.20 (d, $J$ = 7.5 Hz, 2 H), 7.15 (d, $J$ = 7.4 Hz, 1 H), 7.14 (t, $J$ = 7.7 Hz, 1 H), 6.94 (t, $J$ = 7.4 Hz, 1 H), 6.91 (d, $J$ = 7.7 Hz, 1 H), 3.85 (d, $J$ = 1.7 Hz, 1 H), 3.69 (s, 3 H), 3.15−3.07 (m, 2 H), 2.64 (dd, $J$ = 16, 1.7 Hz, 1 H), 2.35 (d, $J$ = 16 Hz, 1 H), 1.95−1.89 (m, 1 H), 1.84−1.76 (m, 2 H), 1.57−1.53 (m, 1 H), 1.21 (t, $J$ = 7.2 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 168.64, 168.47, 143.26, 138.06, 137.80, 128.45, 128.28, 127.86, 127.26, 121.32, 120.61, 109.60, 91.40, 66.92, 62.80, 57.13, 50.79, 44.91, 44.89, 28.05, 27.62, 10.30; MS *m*/*z* (relative intensity) 454 (2), 298 (3), 297 (13), 265 (4), 242 (3), 240 (5), 238 (6), 237 (10), 236 (3), 215 (5), 214 (5), 209 (5), 207 (4), 194 (5), 180 (8), 168 (5), 167 (7), 157 (7), 155 (6), 154 (10), 144 (6), 98 (5), 69 (11), 57 (14), 55 (10), 44 (100). Anal. Calcd for $C_{24}H_{26}N_2O_2Se$: C, 63.42; H, 5.77; N, 6.17; Se, 17.60. Found: C, 63.66; H, 5.69; N, 6.20; Se, 17.57.

**Epimerization Study of *Cis* (2) and *Trans* (3) Isomers.** Heating each isomer at reflux in toluene for 18 h did not result in any epimerization, and only the starting isomer was recovered. However, heating each isomer (10 mg) in toluene with 5 mg of *p*-TsOH·$H_2O$ at reflux for 15 min afforded a ratio of 1:2.5 *cis*/*trans* isomers (determined by integration of the side-chain methyl proton in the $^1H$ NMR spectra) in both cases.

(15) While the second reaction step would require a 5-*endo*-trig cyclization, it should be noted that an analogous formation of the vindolinine skeleton has been accomplished by a reductive cyclization of 19-iodotabersonine with sodium: Hugel, G.; Cartier, D.; Lévy, J. *Tetrahedron Lett.* **1989**, *30*, 4513.

**Methyl (±)-(3a*R**,4*S**,11b*R**)-3-Propargyl-2,3,3a,4,5,7-hexahydro-4-ethyl-4-(phenylselenyl)-1*H*-pyrrolo[2,3-*d*]-carbazole-6-carboxylate (4).** To a solution of 0.050 g (0.11 mmol) of *cis*-amino selenide **2** in 3 mL of dry THF were added 0.164 g (1.1 mmol) of an 80% solution of propargyl bromide in toluene (available from Aldrich) and 0.152 g (1.1 mmol) of potassium carbonate. The mixture was heated at reflux for 40 h, until TLC ($SiO_2$, 9:1 hexane/ethyl acetate) showed that no starting material was left. After cooling and removal of THF with a rotary evaporator, the residue was suspended in 50 mL of water and extracted with methylene chloride (3 × 30 mL). The $CH_2Cl_2$ layer was dried ($Na_2SO_4$) and concentrated. The crude product was purified by silica gel column chromatography, eluting with 9:1 hexane/ethyl acetate, yielding 0.038 g (70.2%) of $N^b$-alkylated product as a white foam: $R_f$ = 0.28 (hexane/ethyl acetate 9:1); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 204, 222, 298, 330 nm; IR (thin film) $\nu_{max}$ 3294, 2968, 2947, 2843, 1677, 1608, 1466, 1438, 1285, 1249, 1231, 1103, 741 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 8.97 (br s, 1 H), 7.75 (dd, $J$ = 7.6, 1.4 Hz, 2 H), 7.62 (d, $J$ = 7.5 Hz, 1 H), 7.33−7.26 (m, 3 H), 7.17 (td, $J$ = 7.7, 0.9 Hz, 1 H), 6.89 (t, $J$ = 7.5 Hz, 1 H), 6.88 (d, $J$ = 7.7 Hz, 1 H), 4.57 (dd, $J$ = 17.6, 2.4 Hz, 1 H), 4.00 (dd, $J$ = 17.6, 2.4 Hz, 1 H), 3.71 (s, 3 H), 3.41 (d, $J$ = 1.5 Hz, 1 H), 3.30−3.20 (m, 2 H), 2.85 (dd, $J$ = 15.3, 1.5 Hz, 1 H), 2.74 (d, $J$ = 15.3 Hz, 1 H), 2.41 (t, $J$ = 2.4 Hz, 1 H), 2.23 (td, $J$ = 12, 7 Hz, 1 H), 1.74 (dd, $J$ = 12, 4.7 Hz, 1 H), 1.29−1.21 (m, 1 H), 1.17−0.97 (m, 1 H), 0.76 (t, $J$ = 7.2 Hz, 3 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.39, 163.94, 143.00, 137.26, 136.84, 128.90, 128.58, 128.11, 128.00, 123.59, 120.62, 109.20, 90.60, 81.36, 73.64, 71.10, 61.07, 58.21, 50.95, 50.90, 44.54, 40.67, 31.76, 28.79, 9.03; MS *m*/*z* (relative intensity) 492 (1), 411 (1), 336 (8), 335 (34), 237 (31), 208 (15), 195 (6), 194 (10), 193 (7), 181 (6), 180 (11), 168 (9), 167 (13), 154 (12), 122 (10), 91 (6), 83 (6), 82 (100), 78 (7).

**Methyl (±)-(3a*R**,4*R**,11b*R**)-3-Propargyl-2,3,3a,4,5,7-hexahydro-4-ethyl-4-(phenylselenyl)-1*H*-pyrrolo[2,3-*d*]-carbazole-6-carboxylate (5).** A solution of 0.164 g (0.36 mmol) of tetracyclic phenyl selenide **3** (*trans*) and 0.258 g (1.73 mmol) of propargyl bromide (80% solution) in 15 mL of dry THF was stirred at 50 °C for 48 h. To the reaction mixture were then added 0.3 g of sodium carbonate and 5 drops of water, and stirring was continued at 40 °C for 24 h. A workup procedure similar to the one for isomer **4** gave 110 mg (61.9%) of $N^b$-alkylated product as a white foam: $R_f$ = 0.24 (9:1 hexane/ethyl acetate); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 204, 220, 300, 332 nm; IR (thin film) $\nu_{max}$ 3297, 2969, 2946, 2831, 1675, 1602, 1476, 1466, 1437, 1304, 1138, 1123, 740 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 9.12 (br s, 1 H), 7.60 (d, $J$ = 7.5 Hz, 1 H), 7.28 (dd, $J$ = 8.0, 1.3 Hz, 2 H), 7.27−7.13 (m, 4 H), 6.94 (td, $J$ = 7.5, 0.9 Hz, 1 H), 6.90 (d, $J$ = 7.7 Hz, 1 H), 3.96 (d, $J$ = 2.0 Hz, 1 H), 3.78 (s, 3 H), 3.52 (dd, $J$ = 17.6, 2.4 Hz, 1 H), 3.47 (dd, $J$ = 17.6, 2.4 Hz, 1 H), 3.22−3.17 (m, 1 H), 3.05 (dd, $J$ = 8.9, 6.4 Hz, 1 H), 2.99 (dd, $J$ = 15.9, 2.0 Hz, 1 H), 2.41 (d, $J$ = 15.9 Hz, 1 H), 2.30 (t, $J$ = 2.4 Hz, 1 H), 2.05 (t, d, $J$ = 12, 6.4 Hz, 1 H), 1.90−1.83 (m, 1 H), 1.72 (dd, $J$ = 12, 5 Hz, 1 H), 1.40−1.35 (m, 1 H), 1.17 (t, $J$ = 7.2 Hz, 3 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.38, 167.94, 143.06, 138.20, 137.86, 128.52, 128.31, 127.88, 127.84, 122.89, 120.63, 109.53, 90.39, 80.49, 73.64, 71.94, 64.63, 58.36, 51.57, 50.99, 43.42, 41.60, 27.12, 26.50, 10.15; MS *m*/*z* (relative intensity) 492 (0.5), 411 (0.2), 336 (3), 335 (14), 280 (2), 268 (2), 252 (2), 237 (13), 236 (3), 221 (3), 194 (6), 180 (7), 168 (6), 167 (7), 155 (4), 154 (7), 83 (6), 82 (100).

**(±)-3-*nor*-14-Methylenevincadifformine (14). Procedure a: from the *Cis* Isomer 4.** A solution of $N^b$-propargyl selenide **4** (66 mg, 0.13 mmol) in 15 mL of dry benzene was degassed with argon for 10 min. To the solution were added 0.056 mL (0.208 mmol, 1.5 equiv) of tri-*n*-butyltin hydride and 1 mg of AIBN. The mixture was stirred under argon at 85 °C for 2 h, at which point TLC showed that there was some starting material left. To this reaction mixture were added a further 0.056 mL of tri-*n*-butyltin hydride and 1 mg of AIBN, and heating was continued for 2 h at 85 °C. TLC then showed the reaction to be complete. The mixture was cooled and concentrated. The residue was purified by flash chromatography on silica gel, eluting with 1:1 hexane/ethyl acetate, to give 29 mg (64.2%) of pure cyclized product: $R_f$ = 0.18 (1:1 hexane/ethyl acetate), 0.22 (ethyl acetate); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 204, 226, 298, 328 nm; IR (thin film) $\nu_{max}$ 3377, 3368, 2966, 2948, 2847, 1676, 1610, 1467, 1436, 1244, 1201, 1121, 1100, 749 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 9.08 (br s, 1 H), 7.45 (d, $J$ = 7.4 Hz, 1 H), 7.17 (t, $J$ = 7.7 Hz, 1 H), 6.93 (t, $J$ = 7.4 Hz, 1 H), 6.84 (d, $J$ = 7.7 Hz, 1 H), 5.13 (s, 1 H), 4.98 (s, 1 H), 3.79 (s, 3 H), 3.78 (d, $J$ = 15 Hz, 1 H), 3.56 (d, $J$ = 15 Hz, 1 H), 3.40−3.49 (m, 1 H), 3.42 (s, 1 H), 2.87 (d, $J$ = 16 Hz, 1 H), 2.80 (t, d, $J$ = 9.7, 6 Hz, 1 H), 2.23−2.34 (m, 1 H), 2.08 (d, $J$ = 16 Hz, 1 H), 1.97−2.07 (m, 1 H), 1.23−1.37 (m, 2 H), 0.75 (t, $J$ = 7 Hz, 3 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.85, 163.79, 155.72, 143.44, 138.21, 127.96, 122.88, 121.34, 109.04, 106.20, 91.25, 78.68, 61.33, 57.54, 54.71, 50.88, 48.78, 40.55, 34.49, 30.87, 8.85; MS *m*/*z* (relative intensity) 337 (M + 1, 4), 336 (17), 277 (2), 269 (2), 214 (3), 204 (2), 167 (3), 154 (6), 123 (9), 122 (100), 107 (4), 86 (52), 84 (50); high-resolution MS, EI, calcd for $C_{21}H_{24}N_2O_2$ 336.1838, found 336.1829.

**Procedure b: From the *Trans* Isomer 5.** The same procedure was repeated starting with 57 mg of $N^b$-propargyl selenide **5** to give 24.6 mg (63.1%) of cyclized product, which showed TLC and spectra identical to those of the product obtained above.

**Methyl (±)-(3a*R**,4*S**,11b*R**)- and (3a*R**,4*R**,11b*R**)-3-Allyl-2,3,3a,4,5,7-hexahydro-4-ethyl-4-(phenylselenyl)-1*H*-pyrrolo[2,3-*d*]carbazole-6-carboxylate (12 and 13).** A mixture of 0.200 g (0.44 mmol) of the *cis* tetracyclic amine **2**, 0.076 mL (0.88 mmol) of allyl bromide, 0.2 g of potassium carbonate, and 5 mL of THF was stirred in an oil bath at 65 °C for 2 d. Filtration and washing with dichloromethane gave a filtrate that was concentrated on a rotary evaporator. The crude product was purified by flash chromatography ($SiO_2$, hexane/ether 3:1) to give 0.157 g of the product **12** (72%) as a white foam: $R_f$ = 0.41 (1:1 ether/hexane); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 206, 224, 300, 332 nm; IR (thin film) $\nu_{max}$ 3383, 3071, 3056, 2971, 2947, 2911, 2850, 2815, 1679, 1611, 1477, 1466, 1436, 1295, 1279, 1249, 1239, 1209, 1118, 1105, 1046, 912, 740, 695 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 8.98 (br s, 1 H), 7.76 (d, $J$ = 7.5 Hz, 2 H), 7.35−7.27 (m, 3 H), 7.18 (t, $J$ = 7.5 Hz, 1 H), 7.16 (d, $J$ = 7.7 Hz, 1 H), 6.92 (t, $J$ = 7.5 Hz, 1 H), 6.82 (d, $J$ = 7.7 Hz, 1 H), 6.19−6.14 (m, 1 H), 5.38 (br d, $J$ = 17.1 Hz, 1 H), 5.19 (d, $J$ = 10.1 Hz, 1 H), 4.21−4.17 (m, 1 H), 3.69 (s, 3 H), 3.47 (dd, $J$ = 13, 8 Hz, 1 H), 3.31 (dd, $J$ = 10, 7 Hz, 1 H), 3.22 (s, 1 H), 3.08 (d, $J$ = 15.3 Hz, 1 H), 2.95 (d, $J$ = 15.3 Hz, 1 H), 2.79−2.73 (m, 1 H), 2.43−2.36 (m, 1 H), 1.75 (dd, $J$ = 12.4, 5.6 Hz, 1 H), 1.30−1.23 (m, 1 H), 0.99−0.96 (m, 1 H), 0.81 (t, $J$ = 7.2 Hz, 3 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.37, 162.77, 143.15, 138.01, 136.65, 135.83, 129.61, 128.46, 128.12, 128.08, 122.97, 120.73, 116.89, 109.26, 91.42, 72.17, 62.01, 61.42, 57.92, 51.43, 50.94, 39.38, 35.04, 29.16, 9.87; MS *m*/*z* (relative intensity) 495 (3), 494 (3), 493 (2), 492 (1), 339 (1), 338 (13), 337 (61), 323 (2), 305 (2), 282 (10), 280 (16), 278 (8), 268 (6), 238 (9), 237 (42), 222 (5), 221 (4), 214 (5), 209 (5), 208 (14), 200 (5), 193 (5), 180 (9), 168 (9), 167 (6), 154 (8), 86 (23), 85 (6), 84 (100), 57 (6). Anal. Calcd for $C_{27}H_{30}N_2O_2Se$: C, 65.57; H, 6.12; N, 5.67; Se, 16.17. Found: C, 65.86; H, 6.17; N, 5.58; Se, 16.44.

**Formation of 13 from the *Trans* Isomer 3.** A mixture of 0.100 g (0.22 mmol) of the *trans* amine **3**, 0.1 mL of allyl bromide, and 0.3 g of potassium carbonate in 4 mL of THF was heated at reflux for 12 h. The workup procedure shown above then gave 0.077 g (71%) of the product as a white foam after chromatographic purification (flash $SiO_2$, 2:1 hexane/ether): $R_f$ = 0.38 (hexane/ether 1:1); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 206, 222, 302, 334 nm; IR (thin film) $\nu_{max}$ 3383, 3071, 3067, 2968, 2944, 2876, 2802, 1676, 1610, 1478, 1466, 1436, 1283, 1248, 1199, 1161, 1122, 1105, 1047, 914, 741 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 9.11 (br s, 1 H), 7.26−7.13 (m, 7 H), 6.96 (t, $J$ = 7.2 Hz, 1 H), 6.91 (d, $J$ = 7.6 Hz, 1 H), 5.91−5.83 (m, 1 H), 5.13 (d, $J$ = 16.9 Hz, 1 H), 5.09 (d, $J$ = 10.1 Hz, 1 H), 3.78 (s, 3 H), 3.59 (s, 1 H), 3.29 (dd, $J$ = 13.7, 3.7 Hz, 1 H), 3.14 (t, $J$ = 7.7 Hz, 1 H), 3.06−3.02 (m, 1 H), 3.01 (d, $J$ = 16 Hz, 1 H), 2.69−2.63 (m, 1 H), 2.41 (d, $J$ = 16 Hz, 1 H), 2.09−1.97 (m, 2 H), 1.71 (dd, $J$ = 12.1, 4.8 Hz, 1 H), 1.43−1.35 (m, 1 H), 1.18 (t, $J$ = 7.1 Hz, 3 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.36, 167.80, 143.14, 138.25, 137.65, 135.39, 128.50, 128.33, 127.95, 127.89, 122.09, 120.68, 116.99, 109.61, 90.45, 74.79, 64.65,

59.83, 57.97, 51.99, 50.96, 41.51, 27.30, 26.05, 10.02; MS *m/z* (relative intensity) 495 (2), 494 (1), 493 (1), 492 (1), 339 (1), 338 (11), 337 (37), 323 (2), 305 (3), 282 (6), 280 (13), 278 (6), 277 (4), 268 (6), 238 (7), 237 (28), 222 (6), 221 (4), 214 (5), 209 (5), 208 (11), 206 (4), 194 (7), 193 (5), 168 (6), 167 (5), 85 (6), 84 (100), 56 (5). Anal. Calcd for $C_{27}H_{30}N_2O_2Se$: C, 65.57; H, 6.12; N, 5.67; Se, 16.17. Found: C, 65.80; H, 6.27; N, 5.52; Se, 16.27.

**(±)-3-*nor*-14-(α and *β*)-Methylvincadifformine (10 and 11). Procedure a: From the *Cis* Isomer 12.** A solution of 0.082 g (0.166 mmol) of the *cis*-*N*-allyl selenide **12**, 0.067 mL (0.249 mmol) of tri-*n*-butyltin hydride, and 5 mg of AIBN in 11 mL of dry benzene was degassed with argon for 10 min and then heated in an oil bath at 85 °C for 3 h. After addition of another 0.067 mL of tri-*n*-butyltin hydride and 5 mg of AIBN, the reaction was continued at 85 °C overnight. Cooling to rt and evaporation gave a residue, which was purified by flash chromatography ($SiO_2$, 0.5:30:70 triethylamine/methanol/ethyl acetate) to give 28 mg of the pure less polar (α-methyl) isomer **10** and 26 mg of a mixture (1:1.3 α/*β*, as determined by integration of $^1$H NMR methyl protons at 0.77 and 0.72 ppm) of isomers **10** and **11**. Total yield: 54 mg (96%, α/*β* 2.6:1).

**For the less polar (α) isomer 10:** $R_f$ = 0.34 (1:1 methanol/ethyl acetate); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 206, 228, 300, 330 nm; IR (thin film) $\nu_{max}$ 3378, 2959, 1676, 1610, 1479, 1466, 1436, 1378, 1309, 1291, 1272, 1244, 1201, 1151, 1108, 1042, 743 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 9.04 (br s, 1 H), 7.31 (d, *J* = 7.4 Hz, 1 H), 7.16 (td, *J* = 7.7, 1.1 Hz, 1 H), 6.88 (td, *J* = 7.4, 0.8 Hz, 1 H), 6.83 (d, *J* = 7.7 Hz, 1 H), 3.78 (s, 3 H), 3.37 (td, *J* = 12.3, 5.2 Hz, 1 H), 3.30 (s, 1 H), 3.10 (dd, *J* = 9.0, 5.5 Hz, 1 H), 3.03 (d, *J* = 9.0 Hz, 1 H), 2.90 (dd, *J* = 12.3, 7.3 Hz, 1 H), 2.80 (dd, *J* = 15.2, 1.4 Hz, 1 H), 2.17 (td, *J* = 12.3, 7.3 Hz, 1 H), 2.09−2.04 (m, 1 H), 1.98 (d, *J* = 15.2 Hz, 1 H), 1.66 (dd, *J* = 12.3, 5.2 Hz, 1 H), 1.18−1.11 (m, 1 H), 1.16 (d, *J* = 7.1 Hz, 1 H), 0.77 (t, *J* = 7.4 Hz, 1 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.82, 164.09, 143.49, 137.16, 127.96, 122.44, 120.87, 109.16, 90.25, 77.98, 63.22, 57.72, 52.11, 50.90, 50.26, 40.77, 39.15, 28.14, 24.58, 16.25, 9.10; MS *m/z* (relative intensity) 340 (M + 2, 1), 339 (M + 1, 8), 338 (M, 14), 307 (1), 216 (1), 214 (1), 208 (1), 206 (1), 194 (1), 193 (1), 192 (1), 191 (1), 180 (1), 168 (1), 167 (1), 154 (2), 125 (10), 124 (100), 122 (1), 110 (1), 109 (2), 108 (1), 95 (1), 94 (1), 80 (1), 56 (1), 55 (1), 54 (1).

For the more polar (*β*) isomer **11**, see below in the hydrogenation procedure.

**Procedure b: from *trans*-*N*$^b$-Allyl Selenyl Isomer 13.** A degassed solution, containing 0.039 g (0.90 mmol) of the *trans*-*N*-allyl compound **13**, 0.031 mL of tri-*n*-butyltin hydride, and 5 mg of AIBN in 5 mL of dry benzene was heated in an oil bath at 85 °C for 3 h. After 0.031 mL of tri-*n*-butyltin hydride and 5 mg of AIBN were added, heating at 85 °C was continued overnight. Cooling to rt and evaporation then gave a residue, which was purified by flash chromatography ($SiO_2$, 0.5:50:50 triethylamine/ethyl acetate/methanol) to afford 0.022 g (82%) of the cyclized product as a 2.6:1 α/*β* methyl mixture.

**Procedure c.** To a solution of 0.014 g (0.042 mmol) of the methylene compound **14** in 1 mL of ethyl acetate, under argon, was added 5 mg of 10% palladium on carbon. The mixture was stirred under 1 atm of hydrogen at rt overnight. Filtration through Celite and washing the residue with dichloromethane gave a combined filtrate, which was concentrated and purified by flash chromatography ($SiO_2$, 0.5:30:70 triethylamine/methanol/ethyl acetate) to give 0.012 g (85%) of the *β*-methyl compound **11**: $R_f$ = 0.24 (1:1 methanol/ethyl acetate); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 206, 228, 300, 330 nm; IR (thin film) $\nu_{max}$ 3376, 2959, 2919, 2878, 2856, 1678, 1609, 1480, 1466, 1436, 1383, 1288, 1273, 1244, 1196, 1144, 1122, 1092, 1046, 745 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 9.01 (br s, 1 H), 7.29 (d, *J* = 7.4 Hz, 1 H), 7.16 (t, *J* = 7.7 Hz, 1 H), 6.87 (t, *J* = 7.4 Hz, 1 H), 6.82 (d, *J* = 7.7 Hz, 1 H), 3.77 (s, 3 H), 3.49 (s, 1 H), 3.35−3.27 (m, 2 H), 2.90 (dd, *J* = 12.4, 7.1 Hz, 1 H), 2.58−2.54 (m, 1 H), 2.55 (d, *J* = 15.2 Hz, 1 H), 2.45−2.40 (m, 1 H), 2.16−2.10 (m, 1 H), 2.00 (d, *J* = 15.2 Hz, 1 H), 1.62 (dd, *J* = 12.2, 5 Hz, 1 H), 1.32−1.21 (m, 2 H), 1.00 (d, *J* = 6.8 Hz, 3 H), 0.72 (t, *J* = 7.5 Hz, 3 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.95, 163.49, 143.56, 136.98, 128.01, 122.45, 120.85, 109.16, 90.19, 76.95, 62.78, 57.84, 52.04, 50.95, 47.84, 40.56, 38.83, 29.22, 25.72, 10.97, 9.32; MS *m/z* (relative intensity) 338 (M$^+$, 3), 209 (0.3), 167 (2), 155 (1), 154 (7), 153 (2), 149 (2), 128 (1), 127 (1), 125 (3), 124 (100), 109 (1), 95 (1), 94 (2), 80 (1), 78 (1), 71 (1), 70 (2), 69 (1), 67 (3), 58 (1), 56 (6), 55 (1), 54 (7), 53 (2).

**Methyl (±)-(3a*R**,4*S**,11b*R**)- and (3a*R**,4*R**,11b*R**)-3-(2-bromoallyl)-2,3,3a,4,5,7-hexahydro-4-ethyl-4-(phenylselenyl)-1*H*-pyrrolo[2,3-*d*]carbazole-6-carboxylate (7 and 8). *cis*-Amino Selenide 7.** A mixture of 0.100 g (0.22 mmol) of the *cis* tetracyclic selenide **2**, 0.52 g of 85% 2,3-dibromopropene (2.2 mmol), and 0.3 g of the potassium carbonate in 3 mL of THF was heated at reflux for 2 d. Filtration and concentration of the filtrate gave a residue, which was purified by flash chromatography ($SiO_2$, hexane/ether 3:1) to afford 0.097 g of the alkylated product (77%) as a white foam: $R_f$ = 0.46 (ether/hexane 1:1); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 212, 226, 300, 332 nm; IR (thin film) $\nu_{max}$ 3381, 3068, 2947, 2872, 1678, 1611, 1478, 1466, 1436, 1386, 1377, 1283, 1248, 1200, 1149, 1126, 1105, 1084, 1046, 1021, 896, 741, 695 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 8.98 (br s, 1 H), 7.72 (d, *J* = 7.5 Hz, 2 H), 7.35−7.25 (m, 3 H), 7.18 (t, *J* = 7.7 Hz, 1 H), 7.11 (d, *J* = 7.5 Hz, 1 H), 6.92 (t, *J* = 7.5 Hz, 1 H), 6.82 (d, *J* = 7.8 Hz, 1 H), 6.22 (s, 1 H), 5.72 (s, 1 H), 4.35 (d, *J* = 15.4 Hz, 1 H), 3.77 (d, *J* = 15.4 Hz, 1 H), 3.69 (s, 3 H), 3.44 (dd, *J* = 9.1, 7.4 Hz, 1 H), 3.14 (d, *J* = 15.4 Hz, 1 H), 3.00 (d, *J* = 15.4 Hz, 1 H), 2.79−2.74 (m, 1 H), 2.47−2.41 (m, 1 H), 1.80 (dd, *J* = 12.4, 5.5 Hz, 1 H), 1.29−1.23 (m, 1 H), 0.96−0.90 (m, 1 H), 0.75 (t, *J* = 7.2 Hz, 3 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.31, 162.47, 143.10, 138.04, 136.23, 129.41, 129.26, 128.50, 128.26, 128.17, 122.79, 120.83, 118.50, 109.36, 91.58, 72.27, 66.26, 61.61, 57.73, 51.83, 50.99, 39.63, 35.29, 28.91, 9.82; MS *m/z* (relative intensity) 574 (1), 572 (2), 433 (3), 431 (4), 429 (2), 418 (10), 417 (52), 416 (14), 415 (51), 378 (5), 376 (6), 362 (6), 360 (17), 358 (15), 357 (5), 356 (7), 355 (4), 336 (4), 335 (5), 296 (6), 291 (24), 289 (27), 268 (21), 254 (10), 253 (8), 252 (21), 239 (7), 238 (27), 237 (95), 236 (13), 235 (9), 224 (12), 222 (21), 221 (15), 220 (10), 214 (24), 209 (17), 208 (43), 207 (17), 196 (13), 195 (17), 194 (27), 193 (17), 182 (18), 181 (18), 180 (30), 170 (11), 169 (20), 168 (24), 167 (27), 164 (100), 162 (96), 157 (24), 155 (22), 154 (41), 144 (11), 143 (17), 130 (13), 122 (10). Anal. Calcd for $C_{27}H_{29}N_2O_2SeBr$: C, 56.65; H, 5.11; N, 4.90; Se, 13.97; Br, 13.96. Found: C, 56.98; H, 5.32; N, 4.68; Se, 13.84; Br, 13.76.

***trans*-Amino Selenide 8.** A mixture of 0.285 g of the *trans* tetracycle **3** (0.63 mmol), 0.74 g (3.15 mmol) of 85% 2,3-dibromopropene, and 0.5 g of potassium carbonate in 5 mL of THF was heated at reflux for 2 d. Filtration and subsequent concentration of the filtrate gave the crude product, which was purified by flash chromatography ($SiO_2$, hexane/ether 2:1) to afford 0.286 g of the product (80%): $R_f$ = 0.50 (hexane/ether 1:1); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 214, 224, 300, 332 nm; IR (thin film) $\nu_{max}$ 3383, 3059, 2969, 2945, 2821, 1678, 1610, 1478, 1466, 1436, 1386, 1283, 1248, 1200, 1149, 1126, 1082, 1047, 906, 741, 695 cm$^{-1}$; $^1$H NMR ($CDCl_3$, TMS) $\delta$ 9.12 (br s, 1 H), 7.26−7.12 (m, 7 H), 6.96 (t, *J* = 7.4 Hz, 1 H), 6.91 (d, *J* = 7.7 Hz, 1 H), 5.90 (s, 1 H), 5.52 (s, 1 H), 3.77 (s, 3 H), 3.61 (s, 1 H), 3.41 (d, *J* = 15.2 Hz, 1 H), 3.29 (d, *J* = 15.2 Hz, 1 H), 3.21 (dd, *J* = 8.9, 6.8 Hz, 1 H), 3.04 (d, *J* = 15.9 Hz, 1 H), 2.61−2.56 (m, 1 H), 2.41 (d, *J* = 15.9 Hz, 1 H), 2.14−2.04 (m, 2 H), 1.73 (dd, *J* = 12.2, 5 Hz, 1 H), 1.36−1.26 (m, 1 H), 1.18 (t, 7.1 Hz, 3 H); $^{13}$C NMR ($CDCl_3$) $\delta$ 168.20, 167.45, 143.07, 138.09, 137.21, 130.96, 128.53, 128.38, 127.97, 127.68, 121.80, 120.67, 117.68, 109.66, 90.47, 74.97, 65.04, 64.60, 57.76, 52.04, 50.92, 41.50, 27.29, 25.59, 9.97; MS m/z (relative intensity) 575 (7), 574 (19), 417 (7), 415 (7), 298 (5), 289 (3), 283 (14), 282 (100), 268 (3), 252 (5), 238 (7), 237 (30), 236 (5), 226 (5), 224 (16), 222 (6), 214 (8), 208 (12), 207 (5), 195 (6), 194 (9), 193 (5), 182 (8), 181 (11), 180 (15), 170 (7), 169 (12), 168 (7), 167 (9), 164 (40), 162 (49), 157 (7), 155 (10), 154 (30), 137 (19), 130 (5), 121 (11), 105 (8). Anal. Calcd for $C_{27}H_{29}N_2O_2SeBr$: C, 56.65; H, 5.11; N, 4.90; Se, 13.97; Br, 13.96. Found: C, 56.32; H, 5.00; N, 4.72; Se, 13.53; Br, 13.75.

**(±)-Vincadifformine (9). Procedure a: from the *Cis* Isomer 7.** The starting vinyl bromide **7** (60 mg, 0.105 mmol), 0.0705 mL of tri-*n*-butyltin hydride (0.262 mmol, 2.5 equiv), and 10 mg of AIBN were mixed in 7.5 mL of benzene. After degassing with argon for 10 min, the resulting solution was

immersed and stirred in an 85 °C oil bath for 2 h. After addition of 0.1 mL of triethylamine, the reaction was continued at 85 °C for 1 h. Cooling to rt and concentration on a rotary evaporator gave a residue, which was purified by flash chromatography (ether/hexane 1:1) to afford 30 mg (85%) of vincadifformine, which matched a known sample in TLC, NMR, IR, and mass spectra.[1]

**Procedure b: from the *Trans* Isomer 8.** The same procedure was repeated, starting with 60 mg of the amino selenide *trans* isomer **8**, to produce 25 mg of vincadifformine (71%).

**(±)-Methyl 3-(2-Ethylprop-2-enyl)-1,2,3,4,5,6-hexahydroazepino[4,5-*b*]indole-5-carboxylate (17).** To a solution of 1.00 g (11.6 mmol) of 2-ethylallyl alcohol in 15 mL of dry ether at 5 °C was added dropwise 0.44 mL (4.63 mmol) of phosphorous tribromide. The reaction mixture was stirred at 15−20 °C for 18 h, diluted with 25 mL of ether, and washed successively with saturated aqueous sodium bicarbonate solution and brine. Drying ($Na_2SO_4$) and concentration then gave the bromide, which was used directly for the next step.

A mixture of 1.00 g (4.09 mmol) of the indoloazepine **1**, all of the above-formed bromide, 1.7 g of potassium carbonate, and 1.7 mL of triethylamine in 20 mL of acetone was stirred vigorously at rt for 2 h. Filtration, washing with acetone, and concentration of the combined filtrate gave the crude product, which was purified by flash chromatography ($SiO_2$, 1:1 ether/hexane) to afford 0.955 g of the alkylated azepine (74.7%): mp 90−91 °C (MeOH); $R_f$ = 0.48 (ether/hexane 2:1); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 208, 228, 284, 292 nm; IR (thin film) $\nu_{max}$ 3399, 3356, 2962, 2915, 2822, 1730, 1648, 1460, 1434, 1340, 1278, 1206, 1162, 1030, 899, 742, 721 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 8.22 (br s, 1 H), 7.46 (d, $J$ = 7.5 Hz, 1 H), 7.19 (d, $J$ = 8.0 Hz, 1 H), 7.14−7.05 (m, 2 H), 4.93 (s, 1 H), 4.89 (s, 1 H), 3.90 (dd, $J$ = 6.5, 2.1 Hz, 1 H), 3.69 (s, 3 H), 3.32 (dd, $J$ = 12.9, 6.6 Hz, 1 H), 3.16 (s, 2 H), 2.97−2.81 (m, 4 H), 2.63−2.58 (m, 1 H), 2.11 (q, $J$ = 7.4 Hz, 2 H), 1.06 (t, $J$ = 7.4 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 172.54, 148.98, 134.79, 132.26, 128.53, 121.35, 119.11, 117.95, 114.11, 110.93, 110.64, 63.71, 57.99, 55.27, 52.06, 45.81, 26.63, 24.34, 12.14; MS *m*/*z* (relative intensity) 313 (M + 1, 8), 312 (M, 33), 239 (3), 216 (3), 215 (13), 214 (12), 203 (3), 202 (21), 184 (5), 183 (14), 182 (18), 170 (6), 169 (7), 157 (5), 156 (35), 155 (5), 154 (13), 144 (5), 143 (7), 129 (7), 128 (7), 112 (8), 111 (19), 110 (100), 99 (9), 98 (16), 97 (6), 96 (74), 82 (20), 69 (5). Anal. Calcd for $C_{19}H_{24}N_2O_4$: C, 73.05; H, 7.74; N, 8.97. Found: C, 73.11; H, 7.75; N, 8.97.

**Methyl (±)-(3a*R**,4*R**,11b*R**)-3-(2-Ethylprop-2-enyl)-2,3,3a,4,5,7-hexahydro-4-(phenylselenyl)-1*H*-pyrrolo[2,3-*d*]carbazole-6-carboxylate (18).** A mixture of 0.107 g (0.34 mmol) of the azepine **17** and 0.072 g (0.36 mmol) of (phenylselenyl)acetaldehyde in 3 mL of dry toluene was heated at reflux for 3 h. After addition of another 0.072 g of (phenylselenyl)-acetaldehyde, the reaction was continued at reflux for 5 h. Cooling and concentration then gave a crude syrup, which was purified by flash column chromatography ($SiO_2$, 4:1 hexane/ether) to afford 0.127 g (75.1%) of the pure product as a viscous oil: $R_f$ = 0.55 (ether/hexane 1:1); CAS spray, yellow; UV (EtOH) $\lambda_{max}$ 206, 220, 300, 332 nm; IR (thin film) $\nu_{max}$ 3379, 3072, 3057, 2964, 2946, 2848, 2803, 1677, 1610, 1477, 1466, 1437, 1385, 1341, 1294, 1279, 1249, 1199, 1151, 1125, 1080, 1054, 1021, 905, 772, 742, 691 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 9.07 (br s, 1 H), 7.40 (d, $J$ = 7 Hz, 2 H), 7.24−7.17 (m, 4 H), 7.14 (d, $J$ = 7.5 Hz, 1 H), 6.91 (t, $J$ = 7.5 Hz, 1 H), 6.87 (d, $J$ = 7.7 Hz, 1 H), 4.89 (s, 1 H), 4.77 (s, 1 H), 3.76 (s, 3 H), 3.49 (br s, 1 H), 3.30 (s, 1 H), 3.19 (d, $J$ = 13.1 Hz, 1 H), 3.04 (br d, $J$ = 15.5 Hz, 1 H), 2.99 (d, $J$ = 13.1 Hz, 1 H), 2.99−2.85 (m, 1 H), 2.86 (dd, $J$ = 15.5, 2.5 Hz, 1 H), 2.56−2.50 (m, 1 H), 2.12−2.00 (m, 3 H), 1.72 (dd, $J$ = 11.9, 4.6 Hz, 1 H), 1.03 (t, $J$ = 7.4 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 168.55, 166.17, 149.01, 142.91, 137.67, 135.14, 129.50, 128.78, 127.85, 127.45, 121.92, 120.71, 110.41, 109.49, 91.46, 73.34, 59.85, 55.43, 51.04, 50.93, 46.75, 42.40, 26.80, 24.59, 12.22; MS *m*/*z* (relative intensity) 495 (2), 493 (1), 338 (10), 337 (8), 335 (1), 314 (1), 312 (1), 310 (2), 280 (2), 278 (2), 277 (1), 240 (2), 228 (2)l 227 (2), 226 (2), 209 (3), 184 (3), 180 (4), 167 (4), 157 (6), 155 (4), 154 (6), 113 (5), 112 (62), 88 (8), 87 (4), 86 (68), 84 (100), 77 (6), 69 (7) 57 (7).

**(±)-Pseudo- and 20-*epi*-Pseudovincadifformine (15 and 16).** To a solution of 0.045 g (0.091 mmol) of the selenide **18** in 6 mL of benzene at 85 °C was added a solution of 0.086 mL (0.32 mmol) of tri-*n*-butyltin hydride in 2 mL of benzene through a syringe pump over 8 h. After removal of the solvent under vacuum with a rotary evaporator, the residue was flash chromatographed ($SiO_2$, 3:1 hexane/ether) to provide 0.021 g (68%) of the product as a 2:1 mixture of $\psi$- and *epi*-$\psi$-vincadifformine (the ratio was determined by $^1H$ NMR integration of the indole proton signals at $\delta$ 8.88 and 8.92).[2]

**(±)-3-Oxovincadifformine (21). Procedure a: from the Tetracyclic Selenide 2 (*Cis* Isomer).** A solution of 50 mg (0.11 mmol) of the selenide **2**, 0.14 mL (1.55 mmol, 14 equiv) of methyl acrylate, and a crystal of AIBN in 10 mL of dry benzene was degassed with argon for 10 min. At 85 °C, a solution of 0.090 mL (0.33 mmol, 3 equiv) of tri-*n*-butyltin hydride and 8 mg of AIBN in 2.5 mL of dry benzene was added over 7 h with a syringe pump. The reaction mixture was concentrated, the residue was dissolved in 10 mL of toluene, and 21 mg (0.11 mmol, 1 equiv) of *p*-toluenesulfonic acid monohydrate was added. The mixture was heated at reflux under nitrogen for 18 h and then cooled and concentrated under vacuum. The crude product was purified by flash chromatography ($SiO_2$, 2 cm × 23 cm), eluting with 4:1 ethyl acetate/hexane. Concentration of appropriate fractions gave 13 mg (34%) of pure 3-oxovincadifformine (**21**), which showed TLC behavior identical to that of a known sample[13] in several different solvent systems. A sample recrystallized from benzene had mp 203−204 °C: $R_f$ = 0.33 (ethyl acetate), 0.48 (4% methanol in methylene chloride), 0.55 (5% methanol in methylene chloride); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 204, 224, 296, 328 nm; IR (thin film) $\nu_{max}$ 3340, 2966, 2948, 2879, 1675, 1656, 1609, 1466, 1435, 1309, 1275, 1242, 1195, 1112, 732 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 9.01 (br s, 1 H), 7.18−7.30 (m, 2 H), 6.86−6.95 (m, 2 H), 4.16 (dd, $J$ = 12, 7.6 Hz, 1 H), 3.79 (s, 3 H), 3.48 (s, 1 H), 3.42 (td, $J$ = 12, 5.5 Hz, 1 H), 2.66 (d, $J$ = 15.4 Hz, 1 H), 2.25−2.46 (m, 2 H), 1.81−2.10 (m, 4 H), 1.37 (td, $J$ = 12, 4 Hz, 1 H), 0.99 (q, $J$ = 7 Hz, 2 H), 0.72 (t, $J$ = 7 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 171.16, 168.35, 164.16, 143.30, 136.14, 128.69, 121.66, 121.24, 109.74, 91.57, 68.29, 57.06, 50.89, 43.21, 40.48, 39.63, 31.11, 30.44, 28.98, 28.33, 7.40; MS *m*/*z* (relative intensity) 353 (M + 1, 8), 352 (35), 321 (2), 277 (1), 229 (4), 228 (16), 227 (100), 222 (2), 215 (5), 214 (32), 206 (3), 196 (10), 195 (57), 194 (5), 182 (7), 168 (13), 167 (13), 154 (19), 138 (6), 73(18), 55 (9).

**Procedure b: from the Tetracyclic Selenide 3 (*Trans* Isomer).** The same procedure was repeated, starting with 50 mg of the *trans* selenide **3**, and 13.9 mg (35.8%) of 3-oxovincadifformine (**21**) was obtained after flash chromatographic purification.

**Methyl (±)-(3a*R**,4*S**,11b*R**)-3-(3-Iodoallyl)-2,3,3a,4,5,7-hexahydro-4-ethyl-4-(phenylselenyl)-1*H*-pyrrolo[2,3-*d*]-carbazole-6-carboxylate (22).** A mixture of 0.325 g (0.717 mmol) of the *cis* tetracyclic selenide **2**, (*Z*)-1,3-diiodopropene[14] (0.5 g, 1.7 mmol), and 0.3 g of potassium carbonate in 6 mL of THF was stirred at rt overnight and then heated at reflux for 6 h. After filtration to remove the solid, the filtrate was concentrated and the crude product purified by flash chromatography ($SiO_2$, hexane/ether 2:1), to afford 0.360 g (81%) of the alkylated product as a white foam: $R_f$ = 0.60 (ether/hexane 1:1); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 212, 222, 300, 332 nm; IR (thin film) $\nu_{max}$ 3379, 3054, 2967, 2946, 2849, 2822, 1678, 1611, 1477, 1465, 1435, 1389, 1380, 1281, 1248, 1209, 1191, 1121, 1104, 1045, 1022, 798, 741, 695 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 9.01 (br s, 1 H), 7.74 (d, $J$ = 8.1 Hz, 2 H), 7.33−7.25 (m, 4 H), 7.17 (t, $J$ = 7.7 Hz, 1 H), 6.94 (t, $J$ = 7.5 Hz, 1 H), 6.80 (d, $J$ = 7.6 Hz, 1 H), 6.64−6.60 (m, 1 H), 6.40 (br d, $J$ = 7.7 Hz, 1 H), 4.11 (ddd, $J$ = 14, 4.3, 1.9 Hz, 1 H), 3.80 (dd, $J$ = 14, 7.8 Hz, 1 H), 3.68 (s, 3 H), 3.30−3.26 (m, 1 H), 3.26 (s, 1 H), 3.05 (d, $J$ = 15.3 Hz, 1 H), 2.95 (d, $J$ = 15.3 Hz, 1 H), 2.93−2.86 (m, 1 H), 2.40−2.34 (m, 1 H), 1.75 (dd, $J$ = 12.4, 5.5 Hz, 1 H), 1.29−1.22 (m, 1 H), 1.01−0.88 (m, 1 H), 0.75 (t, $J$ = 7.2 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 168.14, 162.40, 143.01, 138.32, 137.74, 136.25, 129.33, 128.41, 128.12, 128.03, 122.84, 120.82, 109.22, 91.23, 83.06, 72.33, 61.94, 61.63, 57.82, 51.40, 50.87, 39.25, 34.83, 29.13, 9.77; MS *m*/*z* (relative intensity)

621 (M + 2, 0.54), 620 (M + 1, 0.53), 619 (M, 0.11), 493 (0.66), 465 (0.91), 464 (8.81), 463 (32), 408 (4), 406 (4), 404 (2), 337 (2), 324 (3), 323 (9), 316 (3), 314 (11), 312 (12), 311 (4), 310 (7), 296 (4), 277 (19), 268 (6), 255 (12), 250 (26), 238 (17), 237 (70), 232 (11), 222 (15), 221 (14), 210 (64), 209 (12), 208 (30), 196 (15), 195 (23), 194 (31), 193 (14), 192 (8), 182 (19), 181 (16), 180 (35), 172 (54), 170 (28), 169 (16), 168 (32), 167 (52), 159 (17), 158 (16), 157 (86), 156 (12), 155 (49), 154 (56), 153 (19), 142 (100), 141 (10), 130 (14), 128 (28), 127 (41), 117 (19), 116 (21), 115 (17), 108 (10), 107 (12), 106 (10).

**Methyl (±)-(3a*S***,11b*R***)-3-(3-Iodoallyl)-2,3,3a,7-tetrahydro-4-ethyl-1*H*-pyrrolo[2,3-*d*]carbazole-6-carboxylate (23).** To a solution of 0.189 g (0.305 mmol) of the selenide **22** in 6 mL of dichloromethane at −78 °C was added dropwise 0.116 g of *m*-CPBA (0.67 mmol) in 2 mL of dichloromethane. After 10 min, the temperature was raised to −40 °C, and 0.176 g of triphenylphosphine (0.67 mmol) was added. The mixture was brought to rt, stirred for 30 min, and diluted with 20 mL of dichloromethane. After washing with saturated aqueous sodium bicarbonate solution, the dichloromethane layer was dried ($Na_2SO_4$) and concentrated to give the crude product, which was purified by flash chromatography ($SiO_2$, hexane/ether 2:1) to afford 0.126 g of the pure diene **23** as a yellow foam (89%): $R_f$ = 0.41 (ether/hexane 1:1); CAS spray, green; UV (EtOH) $\lambda_{max}$ 210, 220, 250, 298, 372 nm; IR (thin film) $\nu_{max}$ 3374, 2960, 2839, 1678, 1636, 1603, 1464, 1436, 1387, 1322, 1279, 1252, 1229, 1206, 1145, 1119, 1081, 1041, 881, 744 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 9.19 (s, 1 H), 7.28 (d, $J$ = 7.5 Hz, 1 H), 7.20 (t, $J$ = 7.7 Hz, 1 H), 6.95 (t, $J$ = 7.5 Hz, 1 H), 6.89 (d, $J$ = 7.7 Hz, 1 H), 6.55−6.51 (m, 1 H), 6.38 (br d, $J$ = 7.4 Hz, 1 H), 6.02 (s, 1 H), 3.93−3.76 (m, 2 H), 3.89 (s, 1 H), 3.79 (s, 3 H), 3.05−3.02 (m, 1 H), 2.80−2.76 (m, 1 H), 2.42−2.33 (m, 2 H), 2.19−2.14 (m, 1 H), 1.69 (dd, $J$ = 12.7, 5.7 Hz, 1 H), 1.10 (t, $J$ = 7.4 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 167.37, 164.12, 143.31, 139.24, 135.28, 132.50, 128.04, 123.25, 120.78, 113.29, 109.50, 91.54, 82.42, 70.17, 60.70, 56.51, 50.90, 48.47, 41.94, 25.44, 12.44; MS $m/z$ (relative intensity) 463 (M + 1, 3), 462 (M, 18), 335 (11), 277 (8), 266 (6), 263 (4), 254 (19), 253 (52), 252 (100), 239 (3), 152 (8), 238 (19), 236 (10), 235 (10), 222 (23), 221 (53), 210 (24), 208 (10), 207 (9), 206 (18), 196 (79), 194 (11), 193 (15), 192 (19), 180 (11), 178 (14), 167 (44), 165 (14), 155 (15), 151 (13), 139 (34), 127 (12), 88 (12), 86 (29), 84 (70), 82 (11), 77 (11), 69 (21), 68 (15), 56 (19), 55 (12), 54 (13); high-resolution MS, EI, calcd for $C_{21}H_{23}N_2O_2I$ 462.0804, found 462.0804.

**(±)-Tabersonine (24).** A mixture of 0.070 g (0.15 mmol) of the cyclohexadiene **23**, 0.010 g of palladium diacetate, 0.023 g of triphenylphosphine, 0.020 g of sodium formate, and 0.100 mL of triethylamine in 1 mL of dry acetonitrile was heated at reflux overnight. After cooling and evaporation, the residue was purified by flash chromatography ($SiO_2$, 2:1 hexane/ether) to afford 22 mg (43%) of tabersonine, which showed TLC and spectroscopic behaviors identical with those of a known sample.

**Methyl (±)-(3a*R***,4*R***,11b*R***)-3-(3-Iodoallyl)-2,3,3a,4,5,7-hexahydro-4-ethyl-4-(phenylselenyl)-1*H*-pyrrolo[2,3-*d*]-carbazole-6-carboxylate (25).** A mixture of *trans*-amino phenyl selenide **3** (0.085 g, 0.19 mmol), 0.083 g (0.28 mmol) of (*Z*)-1,3-diiodopropene, and 0.10 g of potassium carbonate in 2 mL of THF was stirred at rt overnight and heated at reflux for 2 h. After cooling, filtration, and washing with dichloromethane, the combined filtrate was concentrated to give a residue, which after flash chromatographic purification ($SiO_2$, 1:1 hexane/ether) afforded 0.090 g of the alkylated product (76%): $R_f$ = 0.50 (hexane/ether 1:3); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 212, 222, 300, 334 nm; IR (thin film) $\nu_{max}$ 3379, 3055, 2966, 2944, 2875, 2831, 2816, 1677, 1610, 1478, 1465, 1436, 1385, 1283, 1248, 1200, 1144, 1123, 1082, 1046, 1021, 897, 796, 773, 741, 695, 669 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 9.11 (br s, 1 H), 7.28−7.15 (m, 7 H), 6.99 (t, $J$ = 7.5 Hz, 1 H), 6.91 (d, $J$ = 7.7 Hz, 1 H), 6.34−6.29 (m, 2 H), 3.78 (s, 3 H), 3.64 (s, 1 H), 3.32 (dd, $J$ = 14.4, 5 Hz, 1 H), 3.25 (dd, $J$ = 14.4, 5 Hz, 1 H), 3.13 (br t, $J$ = 7.7 Hz, 1 H), 3.01 (d, $J$ = 15.9 Hz, 1 H), 2.80−2.75 (m, 1 H), 2.38 (d, $J$ = 15.9 Hz, 1 H), 2.09−1.94 (m, 2 H), 1.73 (dd, $J$ = 12.1, 5 Hz, 1 H), 1.44−1.39 (m, 1 H), 1.18 (t, $J$ = 7.1 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 168.31, 167.49, 143.11, 138.14, 138.06, 137.40, 128.61, 128.43, 127.98, 127.83, 122.02, 120.82, 109.66, 90.48, 83.22, 75.29, 64.26, 60.46, 57.95, 52.36, 50.99, 41.54, 27.36, 26.36, 10.00; MS $m/z$ (relative intensity) 621 (0.44), 620 (0.52), 619 (0.10), 618 (0.12), 495 (0.14), 493 (0.52), 480 (0.63), 465 (0.70), 464 (7.0), 463 (26), 408 (3), 406 (4), 404 (2), 403 (1), 338 (2), 337 (2), 335 (2), 323 (8), 314 (6), 312 (6), 277 (15), 254 (17), 252 (11), 237 (32), 222 (15), 221 (14), 211 (6), 210 (100), 208 (21), 195 (10), 194 (16), 193 (12), 182 (14), 181 (17), 180 (41), 179 (10), 168 (12), 167 (56), 165 (34), 157 (38), 155 (22), 154 (36), 153 (16), 137 (12), 127 (19), 111 (9). Anal. Calcd for $C_{27}H_{29}N_2O_2SeI$: C, 52.36; H, 4.72; N, 4.52. Found: C, 52.76; H, 5.16; N, 4.40.

**Methyl (±)-(3a*S***,11b*R***)-3-(3-Iodoallyl)-2,3,3a,4,5,7-hexahydro-4-(ethylenyl)-1*H*-pyrrolo[2,3-*d*]carbazole-6-carboxylate (26).** To a solution of 0.500 g (0.807 mmol) of the *trans*-amino phenyl selenide **25** in 50 mL of dichloromethane at −75 °C was added dropwise a solution of 0.306 g (1.77 mmol) of *m*-CPBA in 5 mL of dichloromethane. The reaction mixture was stirred at −75 °C for 10 min and then the temperature was raised to −40 °C, and 0.465 g (1.77 mmol) of solid triphenylphosphine was then added. The mixture was warmed to rt and washed with saturated aqueous sodium bicarbonate solution. After drying ($Na_2SO_4$) and concentration, the residue was purified by flash chromatography ($SiO_2$, hexane/ether 3:1) to afford 0.233 g (62%) of the pure product as a white foam: $R_f$ = 0.38 (ether/hexane 1:1); CAS spray, greenish blue; UV (EtOH) $\lambda_{max}$ 206, 220, 298, 330 nm; IR (thin film) $\nu_{max}$ 3376, 3059, 2969, 2948, 2917, 2849, 2805, 1684, 1653, 1636, 1609, 1559, 1540, 1477, 1465, 1457, 1437, 1280, 1247, 1191, 1118, 1041, 910, 733 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 8.86 (br s, 1 H), 7.20 (d, $J$ = 7.4 Hz, 1 H), 7.13 (t, $J$ = 7.7 Hz, 1 H), 6.87 (t, $J$ = 7.4 Hz, 1 H), 6.77 (d, $J$ = 7.7 Hz, 1 H), 6.48−6.41 (m, 2 H), 5.20 (q, $J$ = 6.6 Hz, 1 H), 3.77 (s, 3 H), 3.59−3.54 (m, 1 H), 3.50 (d, $J$ = 15.3 Hz, 1 H), 3.41 (dd, $J$ = 14.6, 6.6 Hz, 1 H), 3.33 (s, 1 H), 3.05 (br t, $J$ = 7.1 Hz, 1 H), 2.87−2.82 (m, 1 H), 2.73 (d, $J$ = 15.3 Hz, 1 H), 2.25−2.19 (m, 1 H), 1.80 (dd, $J$ = 11.9, 4.6 Hz, 1 H), 1.66 (d, $J$ = 6.6 Hz, 3 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 168.14, 165.21, 143.46, 138.00, 137.15, 127.93, 122.02, 120.57, 119.89, 109.21, 109.10, 94.75, 83.55, 72.94, 57.33, 55.90, 50.99, 50.78, 42.26, 20.79, 13.55; MS $m/z$ (relative intensity) 462 (M, 2), 337 (1), 295 (3), 294 (3), 254 (13), 253 (22), 252 (95), 236 (5), 235 (7), 222 (5), 220 (12), 210 (12), 208 (5), 206 (7), 194 (16), 193 (9), 192 (8), 191 (5), 180 (10), 168 (8), 167 (58), 165 (9), 154 (10), 142 (100), 141 (12), 139 (12), 128 (16), 127 (44), 84 (9), 56 (18); high-resolution MS, EI, calcd for $C_{21}H_{23}N_2O_2I$ 462.0804, found 462.0799.

**(±)-18,19-Didehydrotabersonine (27).** A mixture of 0.037 g (0.08 mmol) of the ethylene compound **26**, 0.007 g (0.03 mmol) of palladium acetate, 0.016 g (0.06 mmol) of triphenylphosphine, and 0.056 mL (0.4 mmol) of triethylamine in 1 mL of acetonitrile was stirred under reflux for 3 h. The mixture was cooled and concentrated. The residue was purified by flash chromatography ($SiO_2$, 2:1 hexane/ether) to generate 0.0095 g (36%) of 18,19-didehydrotabersonine: $R_f$ = 0.51 (ether/hexane 1:1); CAS spray, blue; UV (EtOH) $\lambda_{max}$ 206, 224, 302, 330 nm; IR (thin film) $\nu_{max}$ 3368, 3028, 2954, 2922, 2856, 1683, 1653, 1636, 1609, 1559, 1540, 1507, 1473, 1465, 1457, 1437, 1280, 1204, 1183, 1161, 1112, 1103, 1038, 926 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 8.95 (br s, 1 H), 7.25 (d, $J$ = 7.5 Hz, 1 H), 7.14 (td, $J$ = 7.6, 1.2 Hz, 1 H), 6.87 (td, $J$ = 7.5, 0.8 Hz, 1 H), 6.80 (d, $J$ = 7.6 Hz, 1 H), 5.80 (ddd, $J$ = 9.7, 5.0, 1.5 Hz, 1 H), 5.59 (dt, $J$ = 9.7, 1.7 Hz, 1 H), 5.44 (dd, $J$ = 17.7, 11 Hz, 1 H), 4.76 (dd, $J$ = 11, 0.8 Hz, 1 H), 4.52 (dd, $J$ = 17.7, 0.8 Hz, 1 H), 3.76 (s, 3 H), 3.49 (ddd, $J$ = 15.8, 5.0, 1.5 Hz, 1 H), 3.22 (dt, $J$ = 15.8, 1.7 Hz, 1 H), 3.09−3.06 (m, 1 H), 2.98 (d, $J$ = 1 Hz, 1 H), 2.79−2.75 (m, 1 H), 2.66 (dd, $J$ = 14.9, 1 Hz, 1 H), 2.61 (d, $J$ = 14.9 Hz, 1 H), 2.11−2.05 (m, 1 H), 1.82 (dd, $J$ = 11.4, 4.5 Hz, 1 H); $^{13}C$ NMR ($CDCl_3$) $\delta$ 168.91, 166.68, 143.23, 142.23, 137.73, 132.98, 127.71, 124.81, 121.25, 120.63, 115.02, 109.34, 92.79, 69.64, 55.39, 50.99, 50.90, 50.39, 45.68, 44.65, 30.28; MS $m/z$ (relative intensity) 335 (M + 1, 2), 334 (M, 14), 229 (9), 228 (4), 217 (1), 214 (5), 204 (2), 195 (2), 191 (2), 170 (7), 169 (4), 168 (10), 167 (17), 166 (4), 155 (1), 154 (19), 153 (2), 149 (7), 143 (2), 142 (2), 141 (5), 140 (5), 139 (3), 134 (3), 133 (100), 132 (4), 129 (3), 128 (8), 127 (8), 120 (35), 119 (22), 118 (3), 115 (11), 111 (2), 109 (2), 106 (4), 105 (58), 103 (3), 97 (3), 95 (5), 93 (7), 92 (4), 91 (35), 83 (8), 79 (6), 78

(9), 77 (20), 71 (9), 70 (5), 69 (8), 67 (4), 65 (5), 56 (18), 54 (15); high-resolution MS, EI, calcd for $C_{21}H_{22}N_2O_2$ 334.1681, found 334.1680.

**Attempted Tandem Heck Reaction to Vindolinine (28). Formation of Methyl (±)-(3a*S**,11b*R**)-3-Acetyl-2,3,3a,4,5,7-hexahydro-4-(ethylenyl)-1*H*-pyrrolo[2,3-*d*]-carbazole-6-carboxylate (29).** A mixture of 0.013 g (0.028 mmol) of the ethylene compound **26**, 0.0095 g (0.042 mmol) of palladium diacetate, and 0.022 g (0.084 mmol) of triphenylphosphine in 0.5 mL of acetonitrile was heated at reflux for 3 h. After addition of 0.020 mL (0.143 mmol) of triethylamine, the reaction was continued at reflux for 2 h. After cooling and concentration, the residue was flash chromatographed, first eluting with 2:1 hexane/ether to give a trace amount of 18,19-didehydrotabersonine, and then with ether to give 6 mg of the *N*-acetyl derivative **29** (63.1%): $R_f = 0.23$ (ether); CAS spray, yellow; UV (EtOH) $\lambda_{max}$ 206, 226, 298, 328 nm; IR (thin film) $\nu_{max}$ 3364, 3054, 2953, 2925, 2858, 1734, 1685, 1636, 1610, 1466, 1436, 1419, 1273, 1242, 1217, 1191, 1095, 1038, 772, 749 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, TMS) $\delta$ 9.12, 9.04 (2 br s, 2:1, 1 H), 7.20−7.15 (m 1 H), 6.94 (d, $J = 7.2$ Hz, 1 H), 6.88−6.81 (m, 2 H), 5.80, 5.60 (2 qd, $J = 6.6$, 2.2 Hz, 1:2, 1 H), 5.03 and 4.42 (2 s, 1:2, 1 H), 3.90−3.68 (m, 1 H), 3.80, 3.79 (2 s, 2:1, 3 H), 3.53−3.35 (m, 2 H), 3.20, 3.09 (2 d, $J = 19$ Hz, 2:1, 1 H), 2.24−1.96 (m, 1 H), 2.24, 2.16 (2 s, 1:2, 3 H), 1.92−1.88 (m, 1 H), 1.75, 1.70 (2 d, $J = 6.6$ Hz, 2:1, 3 H); MS *m*/*z* (relative intensity) 340 (28), 339 (60), 338 (38), 323 (2), 311 (14), 310 (70), 307 (7), 295 (25), 279 (22), 278 (22), 268 (19), 267 (41), 266 (11), 265 (7), 264 (9), 263 (10), 254 (41), 253 (36), 252 (100), 251 (10), 238 (12), 237 (19), 236 (41), 235 (45), 234 (15), 222 (18), 221 (50), 220 (66), 219 (26), 218 (10), 206 (47), 194 (62), 193 (44), 192 (40), 180 (30), 168 (31), 167 (40), 70 (48), 56 (28).

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**Supporting Information Available:** $^1H$ NMR and $^{13}C$ NMR spectra for compounds **2**−**5**, **7**, **8**, **10**−**14**, **17**, **18**, **21**−**23**, and **25**−**27** (37 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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