$[\alpha]_D$ -10.8° [c 1.02, $CHCl_3$]; IR (neat) 3260, 1730, 1150, 965 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.48 (s, 9 H, t-Bu), 1.70 (d, J = 7.3 Hz, 3 H, Me), 3.33 (d, J_{4-3} = 9.5 Hz, 1 H, H-4), 3.48 (dt, J_{3-4} = 9.5 and J_{3-2} = J_{3-CH} = 7.7 Hz, 1 H, H-3), 3.79 (s, 3 H, COOMe), 3.84 (d, J_{2-3} = 7.7 Hz, 1 H, H-2), 5.48 (dd, J_{trans} = 15.4 and J_{CH-3} = 7.7 Hz, 1 H, =CH), 5.66 (dq, J_{trans} = 15.4 and J_{CH-Me} = 7.3 Hz, 1 H, =CH), 6.55 (br, 1 H, NH); ^{13}C NMR ($CDCl_3$) δ 17.81 (Me), 27.96 (t-Bu), 46.19 (C-3), 52.67 (COOMe), 54.13 (C-4), 59.98 (C-2), 82.50 (COOBu-t), 128.62, 129.17 (each =CH), 168.86, 169.44 (each COO), 171.63 (C-5); MS m/z (rel intensity) 283 (M^+, 2), 197 (14), 183 (62), 182 (base peak), 151 (21), 150 (76), 124 (23), 122 (55), 57 (81). Anal. Calcd for $C_{14}H_{21}NO_5$: C, 59.35; H, 7.47; N, 4.94. Found: C, 59.16; H, 7.51; N, 5.13.

2-*tert*-Butyl methyl (2*R*,3*R*,4*R*)-3-[(*E*)-2-phenylvinyl]-5-oxopyrrolidine-2,4-dicarboxylate (11f): colorless needles from column chromatography on silica gel (hexane/ethyl acetate, 4:1 to 1:1); mp 98-100 °C; $[\alpha]_D$ -27.5° [c 1.09, $CHCl_3$]; IR (KBr) 3280, 1720, 1370, 1160, 970 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.48 (s, 9 H, t-Bu), 3.46 (d, J_{4-3} = 9.5 Hz, 1 H, H-4), 3.70 (dt, J_{3-4} = 9.5 and J_{3-2} = J_{3-CH} = 8.1 Hz, 1 H, H-3), 3.80 (s, 3 H, COOMe), 3.98 (d, J_{2-3} = 8.1 Hz, 1 H, H-2), 6.20 (dd, J_{trans} = 16.0 and J_{CH-3} = 8.1 Hz, 1 H, =CH), 6.60 (d, J_{trans} = 16.0 Hz, 1 H, =CH), 7.3-7.4 (m, 6 H, Ph and NH); ^{13}C NMR ($CDCl_3$) δ 27.99 (t-Bu), 46.41 (C-3), 52.84 (COOMe), 54.02 (C-4), 59.70 (C-2), 82.89 (COOBu-t), 126.40, 126.73, 127.97, 128.64, 133.37, 136.19 (Ph and =CH), 168.63, 169.15 (each COO), 171.08 (C-5); MS m/z (rel intensity) 345 (M^+, 4), 289 (97), 244 (28), 230 (92), 212 (50), 185 (20), 184 (75), 129 (28), 128 (32), 57 (base peak). Anal. Calcd for $C_{19}H_{23}NO_5$: C; 66.07; H, 6.71; N, 4.06. Found: C, 65.80; H, 6.75; N, 4.05.

2-*tert*-Butyl methyl (2*R*,3*R*,4*R*)-3-[(*E*)-2-methoxyvinyl]-5-oxopyrrolidine-2,4-dicarboxylate (11g): colorless liquid from column chromatography on silica gel (hexane/ethyl acetate, 1:1); $[\alpha]_D$ - 12.4° [c 0.97, $CHCl_3$]; IR (neat) 3280, 1730, 1650, 1150, 935 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.48 (s, 9 H, t-Bu), 3.30 (d, J_{4-3} = 9.5 Hz, 1 H, H-4), 3.43 (ddd, J_{3-4} = 9.5, J_{3-CH} = 9.1, and J_{3-2} = 7.7 Hz, 1 H, H-3), 3.55 (s, 3 H, MeO), 3.79 (s, 3 H, COOMe), 3.82 (d, J_{2-3} = 7.7 Hz, 1 H, H-2), 4.73 (dd, J_{trans} = 12.9 and J_{CH-3} = 9.1 Hz, 1 H, =CH), 6.47 (d, 1 H, J_{trans} = 12.9 Hz, 1 H, =CHOMe), 7.05 (br, 1 H, NH); ^{13}C NMR ($CDCl_3$) δ 28.02 (t-Bu), 43.04 (C-3), 52.77 (COOMe), 55.15 (C-4), 56.20 (MeO), 60.65 (C-2), 82.79 (COOBu-t), 100.77 (=CH), 150.38 (=CHOMe), 168.71, 169.15 (each COO), 171.08 (C-5); MS m/z (rel intensity) 299 (M^+, 3), 243 (69), 198 (19), 184 (76), 167 (20), 166 (base peak), 138 (49), 111 (21), 69 (23). Anal. Calcd for $C_{14}H_{21}NO_6$: C, 56.16; H, 7.08; N, 4.68. Found: C, 56.42; H, 7.19; N, 4.65.

1-*tert*-Butyl methyl (2*R,3*R**)-2-[(1*R*,4*R*)-bornylidene-amino]-3-phenylglutarate (13)**: colorless prisms from column chromatography on silica gel (hexane/ethyl acetate, 1:1); mp 103-105 °C; IR (KBr) 3220, 1720, 1370, 1235, 1150 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.43 (s, 9 H, t-Bu), 2.54 (dd, J_{gem} = 17.2 and J_{4-3} = 7.3 Hz, 1 H, one of H-4), 2.85 (dd, J_{gem} = 17.2 and J_{4-3} = 9.3 Hz, 1 H, the other of H-4), 3.65 (ddd, J_{3-4} = 9.3, 7.3, and J_{3-2} = 5.9 Hz, 1 H, H-3), 4.14 (d, J_{2-3} = 5.9 Hz, 1 H, H-2), 6.72 (br, 1 H, NH), 7.2-7.5 (m, 5 H, Ph); ^{13}C NMR ($CDCl_3$) δ 27.86 (t-Bu), 38.46 (C-4), 44.19 (C-3), 63.77 (C-2), 82.16 (COOBu-t), 127.05, 127.24, 128.78, 142.01 (each Ph), 170.45 (C-5), 177.02 (COOBu-t); MS m/z (rel intensity) 261 (M^+, 2), 205 (48), 161 (28), 160 (base peak), 57 (7). Anal. Calcd for $C_{15}H_{19}NO_3$: C, 68.94; H, 7.33, N, 5.36. Found: C, 69.08; H, 7.35; N, 5.26.

General Procedure for the Demethoxycarbonylation of 11a and 11d Leading to (2*R*,3*R*)-5 and 12. The reaction of **11a** is typical. A mixture of **11a** (0.132 g, 0.5 mmol), lithium bromide (0.021 g, 0.5 mmol), water (0.009 g, 0.5 mmol), and dimethyl-2-imidazolidinone (DMI, 5 mL) was heated at 140 °C for 4 h. The mixture was then poured into ice/water and was extracted with diethyl ether (30 mL × 3). The combined extracts were dried ($MgSO_4$) and the solvent was evaporated under reduced pressure. The residue was purified by column chromatography on silica gel with hexane-ethyl acetate (1:1) to give (2*R*,3*R*)-**5** (0.08 g, 80%): $[\alpha]_D$ -30.0° [c 1.02, $CHCl_3$].

Similarly, **11d** was converted (130 °C, 4 h) to **12** in 88% yield. Compound **12** was purified by column chromatography on silica gel (hexane/ethyl acetate, 1:1).

***tert*-Butyl (2*R*)-3-phenyl-5-oxopyrrolidine-2-carboxylate (12)**: pale yellow liquid from column chromatography on silica gel (hexane/ethyl acetate, 4:1); $[\alpha]_D$ -38.9° [c 1.03, $CHCl_3$]; IR (neat) 2960, 1720, 1635, 1170 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.74, 0.90, 1.00 (each s, each 3 H, Me), 1.26 (s, 9 H, t-Bu), 1.3-2.9 (m, 9 H, CH_2 and CH), 3.52 (s, 3 H, COOMe), 3.88 (ddd, J_{3-4} = 9.9, 4.4, and J_{3-2} = 7.3 Hz, 1 H, H-3), 4.03 (d, J_{2-3} = 7.3 Hz, 1 H, H-2), 7.1-7.3 (m, 5 H, Ph); ^{13}C NMR ($CDCl_3$) δ 11.54, 18.98, 19.42 (each Me), 27.39 (camphor), 27.80 (t-Bu), 31.95, 36.11, 36.33, 43.72, 44.74 (camphor and C-4), 47.40 (C-3), 51.37 (COOMe), 54.27 (C-1 of camphor), 69.79 (C-2), 80.89 (COOBu-t), 126.75, 128.13, 128.46, 141.16 (each Ph), 169.87, 172.78 (each COO), 186.33 (C=N); MS m/z (rel intensity) 427 (M^+, 4), 208 (30), 162 (16), 131 (26), 121 (20), 103 (18), 91 (18), 77 (18), 57 (base peak). Anal. Calcd for $C_{26}H_{37}NO_4$: C, 73.03; H, 8.72; N, 3.28. Found: C, 73.11; H, 8.55; N, 3.28.

(2*S*,3*S*)-**12**: ^1H NMR spectrum ($CDCl_3$) δ 0.59, 1.00, 1.01 (each s, each 3 H, Me), 1.29 (s, 9 H, t-Bu), 3.50 (s, 3 H, COOMe), 4.01 (d, J_{2-3} = 7.3 Hz, 1 H, H-2).

Synthesis of β-Resorcylic Macrolides via Organopalladium Chemistry. Application to the Total Synthesis of (*S*)-Zearalenone

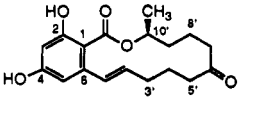
A. Kalivretenos, J. K. Stille,† and L. S. Hegedus*

Department of Chemistry, Colorado State University, Fort Collins, Colorado 80523

Received September 12, 1990

The β-resorcylic macrolides are a class of naturally occurring 12- and 14-membered macrolides. Zearalenone (1), a 14-membered macrolide of this type, displays useful biological activity, which has led to great synthetic interest. In this paper the intramolecular coupling reaction of an organostannane with an electrophile is used to construct β-resorcylic macrolides. The intramolecular coupling of an aryl iodide with a vinylstannane provided the highest yield of lactones. This methodology was then used to prepare (*S*)-zearalenone (1).

The β-resorcylic macrolides are a class of naturally occurring 12- and 14-membered macrolides.[1] Zearalenone (1),[2] a 14-membered macrolide of this type, exhibits anabolic, estrogenic, and antibacterial activity in vitro and in vivo.[1] Commerical applications of this compound have



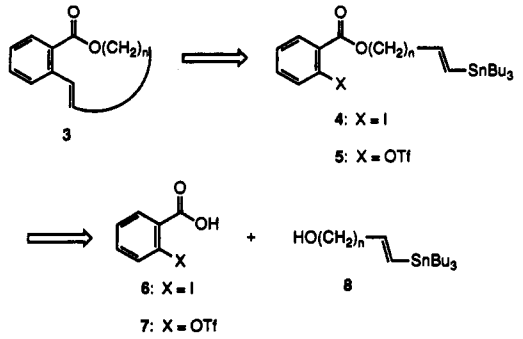
Zearalenone (1)

led to great synthetic interest.[3] The macrocyclic ring of zearalenone has been prepared via intramolecular esteri-

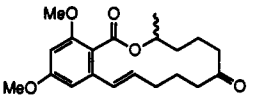
† Deceased.

0022-3263/91/1956-2883$02.50/0

Scheme I



fication reactions[4] or via intramolecular carbon–carbon bond-forming reactions.[3,5] Although zearalenone has been prepared in up to 90% yield,[4b] there are several, general limitations to these methods. Zearalenone has been prepared in racemic form, rather than the naturally occurring *S* enantiomer (except in one case, ref 5d), and has been prepared as (±) protected, 2,4-dimethylzearalenone (**2**).



2,4-dimethylzearalenone (**2**)

The best method for cleavage of the methyl ethers has yielded only 50% of the natural product.[4a] These limitations show the need for an alternate, milder approach for macrocycle construction.

The palladium-catalyzed coupling of an organostannane with an organic electrophile is a good candidate for macrocycle construction (eq 1).[6] A recent report from these

$$RX + R'SnR''_3 \xrightarrow{Pd(0)} RR' + XSnR''_3 \qquad (1)$$

laboratories presented the preparation of medium ring, aliphatic macrolides using this type of palladium-catalyzed macrocyclization as the key step.[7] In this paper, we report the formation of 10–15-membered β-resorcylic macrolides, as well as the total synthesis of (*S*)-zearalenone, using this type of organopalladium chemistry.

Results and Discussion

The synthetic approach to the β-resorcylic macrolides is given in Scheme I and involves the esterification of 2-halo- or 2-trifloxybenzoic acids with (*E*)-vinylstannyl alcohols, followed by the intramolecular coupling of the vinylstannane with the aryl electrophile to construct the macrocycle.

Scheme II

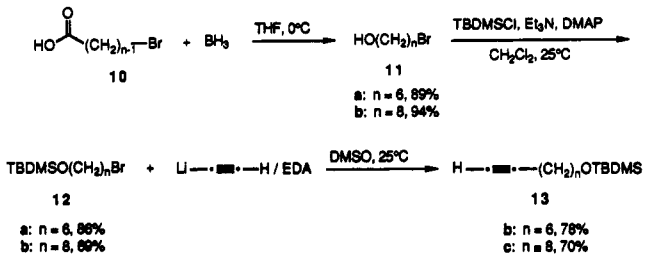
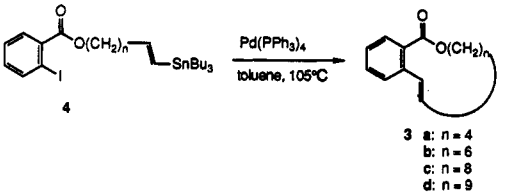


Table I. Cyclization of 4



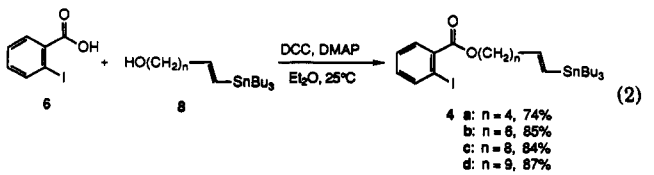
n	conc of **3a** (M)	yield (%)	ring size
4	5×10^{-3}	30, dimer	10
4	Syr[a]	65, dimer	10
6	5×10^{-3}	32	12
6	Syr	37	12
8	5×10^{-3}	49	14
8	Syr	67	14
9	5×10^{-3}	61	15
9	Syr	66	15

[a] Syr: **4** was added to the catalyst solution via a syringe pump over a 5-h period.

The requisite (*E*)-vinylstannyl alcohols **8** were prepared from ω-alkynols **9** via hydrozirconation chemistry.[8] The ω-alkynols **9** were either commercially available (**9a**; *n* = 4; **9d**; *n* = 9) or prepared from ω-bromo carboxylic acids **10** as in Scheme II. Borane reduction of **10** gave the desired alcohol **11** in good yields.[9] The ω-bromo alcohol **11** was protected as the TBDMS (*tert*-butyldimethylsilyl) ether,[10] followed by treatment with lithium acetylide–ethylene diamine complex in DMSO at 25 °C to give the desired alkyne **13**.[11]

Compounds **13** were converted to (*E*)-vinylstannyl alcohols **8** as shown in Scheme III. Treatment of the protected alkynols **13** with Schwartz's reagent[12] provided **14** in up to 72% yield. Lithiation of these vinyl iodides with *n*-BuLi, followed by the addition of Bu_3SnCl, yielded the protected (*E*)-vinylstannane reagents.[13] Crude products were treated with *n*-Bu_4NF to give **8** in up to 98% overall yield from **14**.[14]

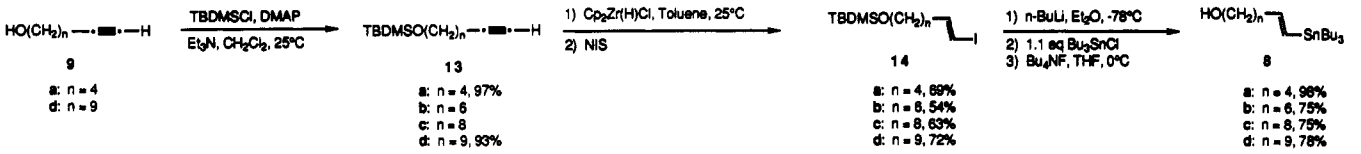
The precursors **4** for the intramolecular coupling reaction of a vinylstannane and an aryl iodide were prepared by DCC-mediated esterification of 2-iodobenzoic acid (**6**) with (*E*)-vinylstannyl alcohols **8**[15] (eq 2). The intramo-



(2)

(1) Omura, S. Macrolide Antibiotics; Academic Press: New York, 1984.
(2) (a) Stob, M.; Baldwin, R. S.; Tuite, J.; Andrews, F. N.; Gillette, K. G. *Nature (London)* **1962**, *196*, 1318. (b) Mirocha, C. J.; Christensen, C. M.; Nelson, G. H. *Appl. Microbiol.* **1967**, *15*, 497. (c) Urry, W. H.; Wehrmeister, H. L.; Hodge, E. B.; Hidy, P. H. *Tetrahedron Lett.* **1966**, 3109.
(3) Shipchandler, M. T. *Heterocycles* **1975**, *3*, 471.
(4) (a) Taub, D.; Girotra, N. N.; Hoffsommer, R. D.; Kuo, C. H.; Slates, H. L.; Weber, S.; Wendler, N. L. *Tetrahedron* **1968**, *24*, 2443. (b) Corey, E. J.; Nicolaou, K. C. *J. Am. Chem. Soc.* **1974**, *96*, 5614. (c) Masamune, S.; Kamata, S.; Schilling, W. *J. Am. Chem. Soc.* **1975**, *97*, 3515. (d) Arnold, L. D.; Assil, H. I.; Vederas, J. C. *J. Am. Chem. Soc.* **1989**, *111*, 3973.
(5) (a) Takahashi, T.; Kasuga, K.; Takahashi, M.; Tsuji, J. *J. Am. Chem. Soc.* **1979**, *101*, 5072. (b) Takahashi, T.; Ikeda, H.; Tsuji, J. *Tetrahedron Lett.* **1981**, *22*, 1363. (c) Rama Rao, A. V.; Deshmukh, M. N.; Sharma, G. V. M. *Tetrahedron* **1987**, *43*, 779. (d) Hitchcock, S. A.; Pattenden, G. *Tetrahedron Lett.* **1990**, *31*, 3641.
(6) (a) Stille, J. K. *Pure Appl. Chem.* **1985**, *57*, 1771. (b) Stille, J. K. *Angew. Chem., Int. Ed. Engl.* **1986**, *25*, 508.
(7) Stille, J. K.; Tanaka, M. *J. Am. Chem. Soc.* **1987**, *109*, 3785.
(8) Negishi, E.; Takahashi, T. *Aldrichimica Acta* **1985**, *18*, 31.
(9) Yoon, N. M.; Pak, C. S.; Brown, H. C.; Krishnamurthy, S.; Stocky, T. P. *J. Org. Chem.* **1973**, *38*, 2786.
(10) Corey, E. J.; Venkateswarlu, A. *J. Am. Chem. Soc.* **1972**, *94*, 6190.
(11) Smith, W. N.; Beumel, O. F., Jr. *Synthesis* **1974**, 441.
(12) Buchwald, S. L.; LaMaire, S. J.; Nielsen, R. B.; Watson, B. T.; King, S. M. *Tetrahedron Lett.* **1987**, *28*, 3895.
(13) Liithy, C.; Konstantin, P.; Untch, K. G. *J. Am. Chem. Soc.* **1978**, *100*, 6211.
(14) Corey, E. J.; Snider, B. B. *J. Am. Chem. Soc.* **1972**, *94*, 2549.

Scheme III



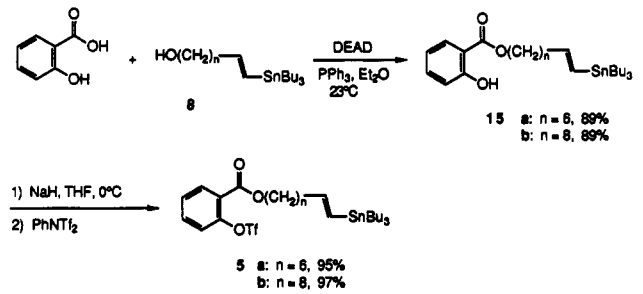
9
a: n = 4
d: n = 9

13
a: n = 4, 97%
b: n = 6
c: n = 8
d: n = 9, 93%

14
a: n = 4, 69%
b: n = 6, 54%
c: n = 8, 63%
d: n = 9, 72%

8
a: n = 4, 98%
b: n = 6, 75%
c: n = 8, 75%
d: n = 9, 78%

Scheme IV



Scheme V

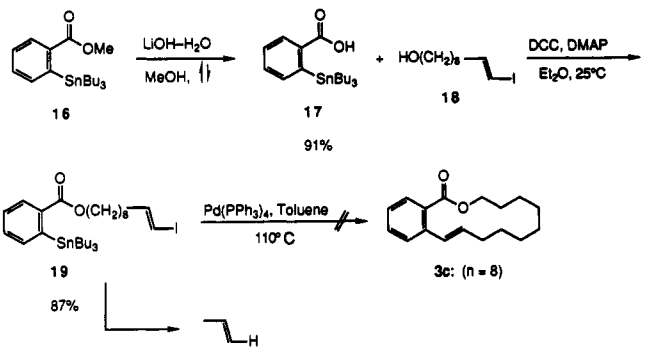
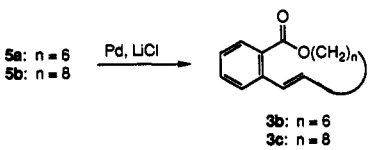
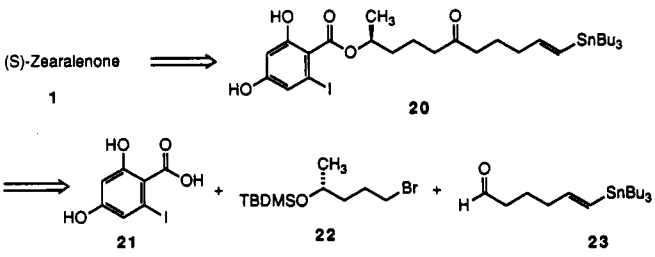


Table II. Cyclization of 5



n (ring size)	temp, °C	cat.	solvent	time, h	yield (%)
6 (12)	100	$Pd(PPh_3)_4$	dioxane	28	0
6 (12)	60	$Pd(PPh_3)_4$	DMF	40	mixture
6 (12)	60	$(PPh_3)_2PdCl_2$	DMF	69	22
8 (14)	70	$(PPh_3)_2PdCl_2$	DMF	72	<5

Scheme VI



lecular coupling reaction of **4** was carried out by using $Pd(PPh_3)_4$ catalyst (2–3 mol %) in toluene at reflux (Table I). The reactions were carried out under high dilution conditions (5×10^{-3} M substrate concentration) or by the slow addition of **4** to a solution of the catalyst in toluene at reflux. In these reactions, starting material was consumed and the major side products were higher order, intermolecular coupling products. The reaction gave fair to good yields of the 12-, 14-, and 15-membered macrocycles, although the formation of the 10-membered system could not be effected. These results indicate that formation of smaller β-resorcylic rings competes less favorably with intermolecular reactions and are in agreement with the results of previous studies on macrolide formation.[16]

The use of aryl trifluoromethanesulfonates (triflates) in palladium-catalyzed coupling reactions with vinylstannanes has been reported.[17] The precursors **5** were prepared to study the utility of these partners in intramolecular coupling reactions (Scheme IV). Esterification of salicylic acid with (*E*)-vinylstannyl alcohols **15** proceeded smoothly in 89% yield under Mitsunobu conditions.[18] Subsequent deprotonation of **15** with NaH,[19] followed by the addition of *N*-phenyltriflimide, afforded **5** in excellent yields.[20] The results of the intramolecular coupling of **5** are given in Table II. All of the reactions were carried out under high dilution conditions (5×10^{-3} M substrate concentration) in the presence of 2–3 mol % of catalyst and 3–4 equiv of LiCl. The reactions gave complex mixtures of products, from which only **3** was isolated.

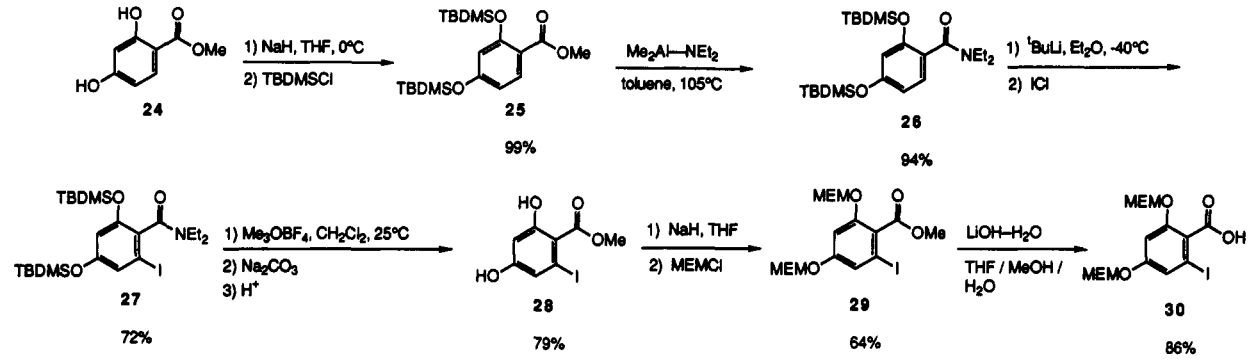
A proposed alternative to this coupling was the use of an arylstannane to couple with a vinyl iodide. The intramolecular coupling of these partners was thus studied (Scheme V). Benzoic acid **17** was prepared by the hydrolysis of ester **16** with $LiOH–H_2O$.[21] Esterification of **17** with (*E*)-10-iodo-9-decen-1-ol (**18**) gave **19**, which upon treatment with $Pd(PPh_3)_4$ in toluene at reflux yielded only starting material and dehalogenated starting material. The absence of coupling may be due to the electron-withdrawing effect of the ortho ester functionality, which deactivates the tin reagent toward coupling.

Of the three intramolecular cyclization reactions studied, the coupling of a vinylstannane with an aryl iodide was by far the best method. This methodology was thus chosen for the synthesis of (*S*)-zearalenone.

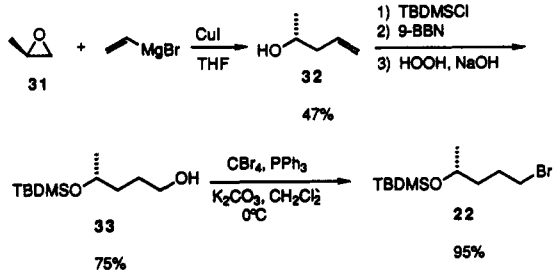
The proposed synthesis of (*S*)-zearalenone, outlined in Scheme VI, involves the coupling of the three precursors **21**, **22** and **23** to yield **20**, followed by the palladium-catalyzed coupling of the vinylstannane and the aryl iodide to construct (*S*)-zearalenone. The tetrasubstituted aryl iodide was synthesized from methyl 2,4-dihydroxybenzoate (**24**) using Meyers' ortholithiation chemistry[22] (Scheme VII). The bis(TBDMS)-protected ester **25** was prepared in 99% yield by treatment of **24** with 2 equiv of NaH in THF, followed by the addition of TBDMSCl. The hindered TBDMS group was utilized to prevent lithiation from occurring at positions ortho to the oxygens on the aryl ring. Compound **25** was treated with the dimethylaluminum–diethylamide reagent via Weinreb's procedure

(15) Hassner, A.; Alexanian, V. *Tetrahedron Lett.* **1978**, 4475.
(16) Galli, C.; Mandolini, L. *J. Chem. Soc., Chem. Commun.* **1982**, 251.
(17) Echavarren, A. M.; Stille, J. K. *J. Am. Chem. Soc.* **1987**, *109*, 5478.
(18) Mitsunobu, O. *Synthesis* **1981**, 1.
(19) Corey, E. J.; Danheiser, R. L.; Chandrasekaran, S.; Siret, P.; Keck, G. E.; Gras, J.-L. *J. Am. Chem. Soc.* **1978**, *100*, 8031.
(20) McMurry, J. E.; Scott, W. J. *Tetrahedron Lett.* **1983**, *24*, 979.
(21) Corey, E. J.; Székely, I.; Shiner, C. S. *Tetrahedron Lett.* **1977**, 3529.
(22) Meyers, A. I.; Avila, W. B. *Tetrahedron Lett.* **1980**, *21*, 3335.

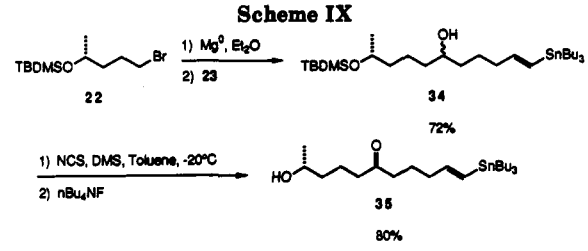
Scheme VII



Scheme VIII



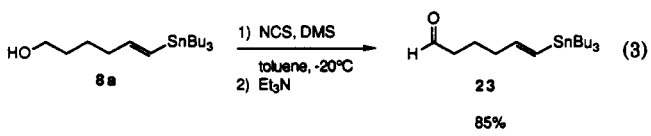
Scheme IX



to yield 94% of **26**.[23] Lithiation of **26** with *t*-BuLi in ether at −40 °C, followed by the addition of a slight excess of ICl gave 72% of **27**.[22] Treatment of aryl iodide **27** with Me_3OBF_4 in CH_2Cl_2 at 25 °C, followed by hydrolysis with Na_2CO_3, afforded 79% of the dihydroxy ester **28**.[24] Attempted hydrolysis of **28** led to low crude yields of acid **21**, which readily underwent decarboxylation. Alternatively, protection of **28** by treatment with NaH and MEMCl afforded 64% of the bis(MEM)-protected ester **29**. Basic hydrolysis gave the protected iodobenzoic acid **30**, which provided the aromatic portion of zearalenone. Upon completion of **30** attention was focused at the preparation of the aliphatic side chain of (*S*)-zearalenone.

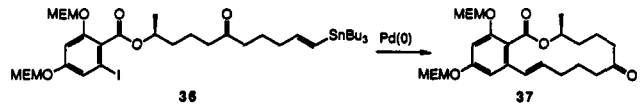
The chiral precursor **22**, (*R*)-[(*tert*-butyldimethylsilyl)-oxy]-1-bromopentane, was prepared as in Scheme VIII. The chiral center was introduced by the use of (*R*)-propylene oxide (prepared by a modified literature procedure[25]). The epoxide **31** was opened upon treatment with vinylmagnesium bromide in the presence of 10% CuI to afford alcohol **32** in 47% yield.[26] Compound **32** was protected as the TBDMS ether and converted to the monoprotected diol **33**, by using hydroboration chemistry, in an overall yield of 75% for the three steps. Compound **33** was converted to the desired bromide **22** in 95% yield, using CBr_4, PPh_3, and K_2CO_3 in CH_2Cl_2 at 0 °C.[27]

The requisite aldehyde, (*E*)-6-(tributylstannyl)-5-hexenol (**23**) was prepared by the oxidation of (*E*)-6-(tributylstannyl)-5-hexen-1-ol (**8a**) in 85% yield, using Corey's method[28] (eq 3).



(3)

Table III. Cyclization of 36



no.	cat.[a]	solvent	temp (°C)	time (h)	concn (M)	yield (%)
1	$Pd(PPh_3)_4$	toluene	105	19	1×10^{-3}	30
2	$(dppf)PdCl_2$[b]	THF	65	112	4×10^{-3}	32
3	$(CH_3CN)_2PdCl_2$	DMF	25	69	4×10^{-3}	
4	$Pd(PPh_3)_4$	toluene	105	14	*c*	39
5	⊕-$Pd(PPh_3)_4$	toluene	105	61	8×10^{-3}	54

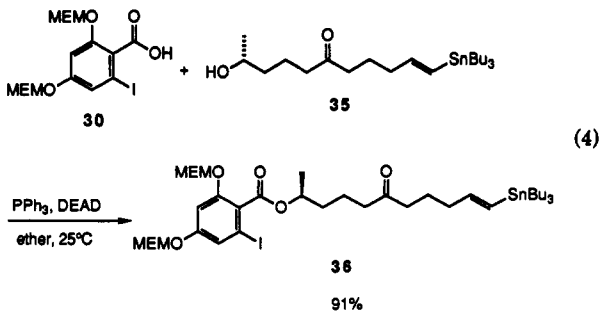
[a] 2–3 mol % of catalyst was used. [b] dppf: 1,1′-bis(diphenylphosphino)ferrocene. [c] Syringe pump addition of substrate.

The aldehyde **23** decomposed slowly and was prepared immediately prior to coupling with bromide **22** for the synthesis of the aliphatic portion of (*S*)-zearalenone according to Scheme IX. The Grignard reagent of **22**, prepared by treatment with Mg metal in ether, was added to a solution of aldehyde **23** in ether, followed by hydrolysis, to give 72% of **34**. The coupled product was oxidized to the ketone, followed by deprotection, to give the aliphatic portion of zearalenone **35** in 80% overall yield for the two steps. Compound **35** existed as a 6:1 mixture of **35** and a compound that appeared to be the six-membered lactol.

The aliphatic portion **35** was coupled with the aromatic portion of zearalenone **30** under Mitsunobu conditions to give 91% of the acyclic precursor to zearalenone **36** (eq 4). Since the Mitsunobu esterification proceeds with inversion of configuration, the desired *S* configuration of **36** was produced.

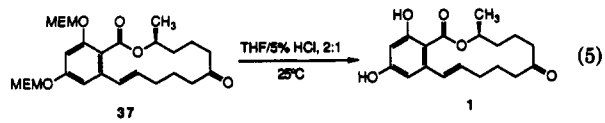
The palladium-catalyzed coupling of **36** to construct the macrocycle **37** was studied; the results are given in Table III. Because of the differences in the electronic nature of **36** relative to the model system **4**, several catalysts were used. The high-dilution and syringe pump methods yielded 32% and 39% of the macrocycle, respectively. These reactions produced a large number of higher order products as observed by TLC and crude ^1H NMR analysis.

(23) (a) Basha, A.; Lipton, M.; Weinreb, S. M. *Tetrahedron Lett.* **1977**, 4171. (b) Lipton, M.; Basha, Aj.; Weinreb, S. M. *Org. Synth.* **1980**, *59*, 49.
(24) Weintraub, L.; Oles, S. R.; Kalish, N. *J. Org. Chem.* **1968**, *33*, 1679.
(25) Hillis, L. R.; Ronald, R. C. *J. Org. Chem.* **1981**, *46*, 3348.
(26) Huynh, C.; Derguini-Boumechal, F.; Linstrumelle, G. *Tetrahedron Lett.* **1979**, 1503.
(27) Downie, I. M.; Holmes, J. B.; Lee, J. B. *Chem. Ind.* **1966**, 900.
(28) Corey, E. J.; Kim, C. U. *Tetrahedron Lett.* **1974**, 287.



Use of the $Pd(PPh_3)_4$ catalyst (~0.1 mmol/g polymer) on a 20% cross-linked polystyrene support in toluene at reflux afforded 54% of the desired macrocycle **37**.[29]

The coupled product **37** was efficiently hydrolyzed with acid to yield 80% of the naturally occurring (*S*)-zearalenone (**1**) (eq 5). The overall yield of (*S*)-zearalenone from (*R*)-propylene oxide (**31**) was 7.6%. This result compares favorably with previous syntheses in which (±)-zearalenone or (±)-2,4-dimethylzearalenone (**2**) were prepared in less than 5% overall yield.



The methodology developed above should be generally useful for the synthesis of macrolide systems.

Experimental Section

General. All solvents were distilled from calcium hydride unless otherwise noted. Dry tetrahydrofuran (THF) and diethyl ether (ether) were distilled from sodium–benzophenone ketyl. Hexane and ethyl acetate (EtOAc) were distilled under an argon (Ar) atmosphere. Dioxane was distilled from Na metal. Ethanol (EtOH) (Midwest Solvents) and methanol (MeOH) (EM Science) were anhydrous. Starting materials were obtained either from Aldrich Chemical Co. or from other commercial suppliers and were used as obtained unless otherwise noted. The following catalysts have been previously prepared in these laboratories by literature procedures: bis(acetonitrile)palladium(II) chloride [$(CH_3CN)_2PdCl_2$],[30] bis(triphenylphosphine)palladium(II) chloride [$(PPh_3)_2PdCl_2$],[31] [1,1′-bis(diphenylphosphino)ferrocene]palladium(II) chloride [Pd(dppf)Cl_2],[32] and tetrakis(triphenylphosphine)palladium(0) [$Pd(PPh_3)_4$] on a polystyrene support.[29] The following reagents were prepared according to literature procedures: $Pd(PPh_3)_4$,[33] *N*-phenyltrifluoromethanesulfonimide (*N*-phenyltriflimide, $PhN(Tf)_2$),[34] and hexabutylditin [$(Bu_3Sn)_2$].[35]

^1H and ^{13}C NMR spectra were recorded on either an IBM WP-200 (200 MHz ^1H), an IBM WP-270 (270 MHz ^1H, 68 MHz ^{13}C), or a Bruker AC300P (300 MHz ^1H, 75.5 MHz ^{13}C) instrument. The following deuterated solvents were used: deuteriochloroform ($CDCl_3$) with tetramethylsilane (TMS) (0.00 ppm ^1H) or chloroform (77.00 ppm ^{13}C), acetone-d_6 with acetone (2.04 ppm ^1H, 29.80 ppm ^{13}C), and dimethyl sulfoxide-d_6 (DMSO-d_6) with DMSO (2.49 ppm ^1H, 39.5 ppm ^{13}C) as internal references. Infrared spectra were recorded on either a Beckman 4240 spectrometer or a Perkin-Elmer 1600 series FT-IR spectrometer. Melting points were obtained on a Mel-Temp melting point apparatus and are uncorrected. The optical rotations were obtained on a Rudolph Research AutoPol III polarimeter. Elemental analyses were performed by Atlantic Microlab, Atlanta, GA. Low resolution mass spectra were obtained on a VG Micromass 16F spectrometer. High resolution mass spectra were obtained from the Midwest Center for Mass Spectrometry, Lincoln, NE.

All reactions were carried out under an atmosphere of argon. All yields reported are isolated yields of products with purity based on thin-layer chromatography (TLC) and NMR spectroscopy. TLC and preparative TLC (PTLC) were performed on Baker (0.25 mm) glass-backed, pre-coated silica gel plates (Si254 F). Silica gel chromatography employed Universal Scientific 62-200 gel for gravity column chromatography and 32-63 gel for flash chromatography.

6-Bromo-1-hexanol (11a). In a dry 50-mL flask, 1.50 g (7.67 mmol) of ω-bromohexanoic acid was added to 12 mL of THF. The solution was cooled to 0 °C, followed by the dropwise addition of 8.4 mL of a 1.0 M solution of borane in THF (8.4 mmol, 1.1 equiv) to the mixture. The mixture was allowed to warm to 25 °C and was stirred for 30 min longer. At this time, the mixture was quenched with 10 mL of a 1:1 solution of water and THF. The aqueous layer was saturated with solid NaCl. The aqueous layer was separated from the organic layer and was extracted with three 25-mL portions of ether. The combined organic extracts were washed with one 20-mL portion of a saturated $NaHCO_3$ solution and dried over anhydrous Na_2SO_4. The dried solution was filtered through a plug of Celite and the solvent was removed in vacuo to yield 1.31 g (94.2%) of a pale yellow oil: IR (neat) ν 3700–3100 (b, OH), 3000–2800, 1460, 1440, 1260, 1050 (C–O) cm^{-1}; ^{13}C NMR ($CDCl_3$) δ 24.79, 27.78, 32.16, 32.55, 33.75 (CH_2Br), 62.40 (CH_2OH). The ^1H NMR spectrum was consistent with published data.[35]

8-Bromo-1-octanol (11b). Compound **11b** was prepared from ω-bromooctanoic acid by the method used for the preparation of **11a** in 94% yield. The ^1H NMR spectrum was consistent with an authentic sample purchased from Aldrich.

1-Bromo-6-[(*tert*-butyldimethylsilyl)oxy]hexane (12a). In a 50-mL flask, 2.607 g (14.40 mmol) of 6-bromo-1-hexanol (**11a**), 2.774 g (18.40 mmol, 1.280 equiv) of TBDMSCl, 0.29 g (4.0 mL, 29 mmol, 2.0 equiv) of Et_3N, and 0.174 g (1.42 mmol, 0.099 equiv) of DMAP were added to 25 mL of CH_2Cl_2. The mixture was stirred for 11 h at 25 °C, during which time a white precipitate formed. At this time, 75 mL of ether was added to the mixture. The solution was washed with one 40-mL portion of water. The aqueous layer was extracted with two 30-mL portions of ether. The combined organic extracts were washed with one 30-mL portion of water, one 40-mL portion of a saturated brine solution, and dried over anhydrous $MgSO_4$. The solution was filtered and the filtrate was concentrated in vacuo to yield an oil. The crude material was purified by chromatography on silica gel (60–200 mesh, hexanes) to yield 3.660 g (86.1%) of a colorless oil (bp 96–98 °C, 0.85 mmHg): R_f 0.61 in 5% EtOAc/hexanes; IR (neat) ν 3000–2800, 1470, 1460, 1250 (Si–C), 1095 (Si–O–C), 824 (Si–O–C), 765 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.05 (s, 6 H, $Si(CH_3)_2$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 1.35–1.55 (m, 6 H), 1.85 (m, 2 H, CH_2CH_2OSi), 3.40 (t, 2 H, J = 6.8 Hz, CH_2Br), 3.61 (t, 2 H, J = 6.3 Hz, $SiOCH_2$); ^{13}C NMR ($CDCl_3$) δ −5.31 ($SiCH_3$), 18.32 ($SiC(CH_3)_3$), 25.01, 25.94 ($SiC(CH_3)_3$), 27.96, 32.58, 32.79, 33.75 (CH_2Br), 62.96 ($SiOCH_2$). This compound was carried on to **13b**.

1-Bromo-8-[(*tert*-butyldimethylsilyl)oxy]octane (12b). Compound **12b** was prepared from **11b** by the method used for the preparation of **12a** in 69% yield: R_f 0.63 in 5% EtOAc/hexanes; IR (neat) ν 3000–2800, 1471, 1254 (Si–C), 1101 (Si–O–C), 836 (Si–O–C), 775 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.00 (s, H, $Si(CH_3)_2$), 0.86 (s, 9 H, $SiC(CH_3)_3$), 1.20–1.55 (m, 10 H), 1.83 (m, 2 H, CH_2CH_2OSi), 3.37 (t, 2 H, J = 6.8 Hz, CH_2Br), 3.57 (t, 2 H, J = 6.4 Hz, CH_2OSi); ^{13}C NMR ($CDCl_3$) δ −5.27 ($Si(CH_3)_2$), 18.36 ($SiC(CH_3)_3$), 25.69, 25.97 ($SiC(CH_3)_3$), 28.11, 28.73, 29.21, 32.80, 33.97, 63.23 (CH_2OSi). Anal. Calcd for $C_{14}H_{31}OSiBr$: C, 52.00; H, 9.66. Found: C, 52.22; H, 9.75.

8-[(*tert*-Butyldimethylsilyl)oxy]-1-octyne (13b). To a flask was added 4.650 g (50.51 mmol, 1.100 equiv) of lithium acetyl-

(29) (a) Pittman, C. U.; Ng, Qj. *J. Organomet. Chem.* **1978**, *153*, 85. (b) Trost, B. M.; Keinan, E. *J. Am. Chem. Soc.* **1978**, *100*, 7779.
(30) Doyle, J. R.; Slade, P. E.; Jonassen, H. B. *Inorg. Synth.* **1960**, *6*, 216.
(31) Itatani, H.; Bailar, J. C. *J. Am. Oil. Chemists Soc.* **1967**, *44*, 147.
(32) Hayashi, T.; Konishi, M.; Kobori, Y.; Kumada, M.; Higuchi, T.; Hirotsu, K. *J. Am. Chem. Soc.* **1984**, *106*, 158.
(33) Coulson, D. R. *Inorg. Synth.* **1972**, *13*, 121.
(34) Hendrickson, J. B.; Bergeron, R. *Tetrahedron Lett.* **1973**, *46*, 4607.
(35) Schore, N. E.; Turro, N. J. *J. Am. Chem. Soc.* **1975**, *97*, 2488.
(36) (a) Herold, T.; Schrott, U.; Hoffman, R. W.; Schnelle, G.; Ladner, W.; Steinbach, K. *Chem. Ber.* **1981**, *114*, 359. (b) Jadhav, P. K.; Bhat, K. S.; Perumal, T.; Brown, H. C. *J. Org. Chem.* **1986**, *51*, 432.

ide–ethylene diamine complex in 70.0 mL of DMSO. The suspension was stirred for several minutes, followed by the addition of 13.572 g (45.95 mmol) of 1-bromo-6-[(*tert*-butyldimethylsilyl)oxy]hexane (**12a**) to the flask. The reaction mixture was stirred at 25 °C for 42 h, followed by the addition of 50 mL of water to the mixture. The mixture was extracted with three 100-mL portions of ether. The combined organic extracts were washed with one 100-mL portion of water and one 100-mL portion of a saturated brine solution and dried over anhydrous $MgSO_4$. The extracts were filtered and the filtrate was concentrated in vacuo to yield an orange/brown oil. Purification of the oil by distillation (78–80 °C, 0.85 mmHg) yielded 8.584 g (77.7%) of a clear oil: R_f 0.61 in 5% EtOAc/hexanes; IR (neat) ν 3320 (C≡*C*—*H*), 3000–2800, 2105 (C≡C), 1470, 1460, 1250 (Si–C), 1100 (Si–O–C), 825 (Si–O–C), 765 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.04 (s, 6 H, $Si(CH_3)_2$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 1.34–1.55 (m, 8 H), 1.93 (t, 1 H, J = 2.6 Hz, C≡C—*H*), 2.18 (dt, 2 H, J = 2.6, 6.9 Hz, $CH_2C{\equiv}C$), 3.60 (t, 2 H, J = 6.4 Hz, CH_2OSi); ^{13}C NMR ($CDCl_3$) δ -5.30 ($Si(CH_3)_2$), 18.33 ($SiC(CH_3)_3$), 25.30, 25.95 ($SiC(CH_3)_3$), 28.48, 32.68, 63.09 (CH_2OSi), 68.07 ($CH_2C{\equiv}CH$), 84.59 ($CH_2C{\equiv}CH$). Anal. Calcd for $C_{14}H_{21}OSi$: C, 69.93; H, 11.74. Found: C, 70.04; H, 11.67.

10-[(*tert*-Butyldimethylsilyl)oxy]-1-decyne (13c). Compound **13c** was prepared from **12b** by the method used for the preparation of **13b** in 70% yield (bp 109 °C, 1.1 mmHg): R_f 0.66 in 5% EtOAc/ hexanes; IR (neat) ν 3313 (C≡*C*—*H*), 2930, 2857, 2119 (C≡C), 1472, 1255 (Si–C), 1097 (Si–O–C), 836 (Si–O–C), 775 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.05 (s, 6 H, $Si(CH_3)_2$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 1.25–1.60 (m, 12 H), 1.94 (t, 1 H, J = 2.6 Hz, C≡C—*H*), 2.18 (dt, 2 H, J = 2.6, 7.0 Hz, $CH_2C{\equiv}CH$), 3.60 (t, 2 H, J = 6.6 Hz, CH_2OSi); ^{13}C NMR ($CDCl_3$) δ -5.26 ($Si(CH_3)_2$), 18.37 ($SiC(CH_3)_3$), 25.74, 25.98 ($SiC(CH_3)_3$), 28.46, 28.69, 29.07, 29.28, 32.84, 63.28 (CH_2OSi), 68.04 (C≡*C*H), 84.75 ($CH_2C{\equiv}C$). This compound was carried on to **14c**.

11-[(*tert*-Butyldimethylsilyl)oxy]-1-undecyne (13d). A solution of 3.320 g (19.73 mmol) of 10-undecyn-1-ol (**9d**), 4.06 g (40.1 mmol, 2.03 equiv) of Et_3N, and 0.243 g (1.99 mmol, 0.101 equiv) of DMAP in 40 mL of CH_2Cl_2 was cooled to 0 °C, followed by the addition of 3.643 g (24.17 mmol, 1.225 equiv) of TBDMSCl. After 10 min, the cold bath was removed and the mixture was stirred for 5 h at 25 °C, during which time a white precipitate formed. The mixture was diluted with 100 mL of ether and 50 mL of water. The layers were partitioned and the aqueous layer was extracted with two 50-mL portions of ether. The combined organic extracts were washed with one 50-mL portion of water and one 50-mL portion of a saturated brine solution. The organic layer was dried over anhydrous Na_2SO_4 and filtered, and the filtrate was concentrated in vacuo to yield a yellow oil. Distillation of the crude mixture yielded 4.614 g (82.8%) of a clear oil (bp 116–117 °C, 0.8 mmHg): R_f 0.66 in 5% EtOAc/hexanes; IR (neat) ν 3320 (C≡*C*—*H*), 3000–2800, 2110 (C≡C), 1460, 1250 (Si–C), 1090 (Si–O–C), 825 (Si–O–C), 765 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.05 (s, 6 H, $Si(CH_3)_2$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 1.30–1.55 (m, 12 H), 1.94 (t, 1 H, J = 2.6 Hz, C≡C—*H*), 2.18 (dt, 2 H, J = 2.6, 7.0 Hz, $CH_2C{\equiv}C$), 3.59 (t, 2 H, J = 6.6 Hz, CH_2OSi); ^{13}C NMR ($CDCl_3$) δ -5.26 ($Si(CH_3)_2$), 18.37 ($SiC(CH_3)_3$), 25.77, 25.97 ($SiC(CH_3)_3$), 28.47, 28.73, 29.04, 29.37, 29.46, 32.86, 63.30 (CH_2OSi), 68.02 (C≡*C*—H), 84.77 ($CH_2C{\equiv}C$). Anal. Calcd for $C_{17}H_{34}OSi$: C, 72.27; H, 12.15. Found: C, 72.33; H, 12.10.

6-[(*tert*-Butyldimethylsilyl)oxy]-1-hexyne (13a). A solution of 5.037 g (51.32 mmol) of 5-hexyn-1-ol (**9a**), 10.38 g (14.30 mL, 102.6 mmol, 2.00 equiv) of Et_3N, and 0.631 g (5.16 mmol, 0.100 equiv) of DMAP was cooled to 0 °C, followed by the addition of 9.396 g (62.34 mmol, 1.215 equiv) of TBDMSCl to the mixture. The cold bath was removed after 0.5 h, and the mixture was stirred at 25 °C for 4 h longer. The reaction mixture was partitioned between 100 mL of water and 100 mL of CH_2Cl_2. The organic extract was washed with two 100-mL portions of a saturated $CuSO_4$ solution and dried over anhydrous $MgSO_4$. The suspension was filtered and the filtrate was concentrated in vacuo to yield a yellow oil. Purification by silica gel chromatography (30 g of gravity gel, hexanes) yielded 10.533 g (96.6%) of a clear oil: R_f 0.70 in 5% EtOAc/hexanes; IR (neat) ν 3318 (C≡*C*—*H*), 3000–2800, 2100 (C≡C), 1468, 1250 (Si–C), 1100 (Si–O–C), 822 (Si–O–C), 760 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.04 (s, 6 H, $Si(CH_3)_2$), 0.89 (s, 9 H, $SiC(CH_3)_3$), 1.61 (m, 4 H), 1.94 (t, 1 H, J = 2.6 Hz, C≡C—*H*), 2.21 (dt, 2 H, J = 2.6, 6.8 Hz, $CH_2C{\equiv}C$), 3.63 (t, 2 H, J = 5.9 Hz, CH_2OSi); ^{13}C NMR ($CDCl_3$) δ -5.33 ($Si(CH_3)_2$), 18.20, 18.32 ($SiC(CH_3)_3$), 24.95, 25.94 ($SiC(CH_3)_3$), 31.81, 62.57 (CH_2OSi), 68.23 (C≡*C*—H), 84.49 ($CH_2C{\equiv}C$). Anal. Calcd for $C_{12}H_{24}OSi$: C, 67.86; H, 11.39. Found: C, 68.00; H, 11.38.

(*E*)-1-Iodo-11-[(*tert*-butyldimethylsilyl)oxy]-1-undecene (14d). To a foil-wrapped flask were added 3.63 g (14.1 mmol, 1.05 equiv) of $Cp_2Zr(H)Cl$ and 120 mL of toluene. The suspension was stirred for 1.5 h at 25 °C, followed by the addition of 3.788 g (13.41 mmol) of 11-[(*tert*-butyldimethylsilyl)oxy]-1-undecyne (**13d**) to the mixture. After 30 h at 25 °C, the mixture was homogeneous and 3.370 g (14.98 mmol, 1.117 equiv) of NIS was added to the solution. The solution was stirred for 62 h, followed by filtration through a plug of silica gel (eluted with 100 mL of ether). The filtrate was diluted with 100 mL of ether and washed with one 100-mL portion of water, two 100-mL portions of a saturated $NaHCO_3$ solution, and one 100-mL portion of a saturated $Na_2S_2O_3$ solution. The organic extract was dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo to yield an orange oil with some solid present. Purification by silica gel chromatography (75 g of gravity gel, 0–3% EtOAc in hexanes) yielded 3.983 g (72.4%) of a faint pink oil: R_f 0.65 in 5% EtOAc/hexanes); IR (neat) ν 3040 (C=*C*—*H*), 2950–2850, 1600 (C=C), 1460, 1250 (Si–C), 1090 (Si–O–C), 825 (Si–O–C), 765 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.02 (s, 6 H, $Si(CH_3)_2$), 0.87 (s, 9 H, $SiC(CH_3)_3$), 1.20–1.55 (m, 14 H), 2.03 (m, 2 H, $CH_2CH{=}CHI$), 3.57 (t, 2 H, J = 6.6 Hz, CH_2OSi), 5.94 (d, 1 H, J = 14.4 Hz, CH=C*H*I), 6.48 (dt, 1 H, J = 7.1, 14.3 Hz, C*H*=CHI); ^{13}C NMR ($CDCl_3$) δ -5.19 ($Si(CH_3)_2$), 18.38 ($SiC(CH_3)_3$), 25.89, 26.05 ($SiC(CH_3)_3$), 28.47, 28.95, 29.32, 29.43, 29.53, 32.97, 36.02, 63.31 (CH_2OSi), 74.04 (CH=*C*HI), 146.77 (*C*H=CHI); HRMS calcd for $C_{17}H_{35}OSiI$ 410.1492; found 353.0782 $(M^+ - C_4H_9)^+$.

(*E*)-1-Iodo-6-[(*tert*-butyldimethylsilyl)oxy]-1-hexene (14a). Compound **14a** was prepared from **13a** by the method used for the preparation of **14d** in 69% yield: R_f 0.64 in 5% EtOAc/hexanes; IR (neat) ν 3049 (C=*C*—*H*), 3000–2800, 1606 (C=C), 1471, 1255 (Si–C), 1105 (Si–O–C), 836 (Si–O–C), 775 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.04 (s, 6 H, $Si(CH_3)_2$), 0.88 (s, 9 H, $SiC(CH_3)_3$), 1.48 (m, 4 H), 2.08 (m, 2 H, $CH_2CH{=}CHI$), 3.60 (t, 2 H, J = 6.1 Hz, $SiOCH_2$), 5.98 (dt, 1 H, J = 1.5, 14.3 Hz, CH=C*H*I), 6.51 (dt, 1 H, J = 7.2, 14.3 Hz, C*H*=CHI); ^{13}C NMR ($CDCl_3$) δ -5.31 ($Si(CH_3)_2$), 18.32 ($SiC(CH_3)_3$), 24.64, 25.94 ($SiC(CH_3)_3$), 31.98, 35.77, 62.75 ($SiOCH_2$), 74.53 (CH=*C*HI), 146.50 (*C*H=CHI); HRMS calcd for $C_{12}H_{25}OSiI$ 340.0712, found 283.0014 $(M^+ - C_4H_9)^+$.

(*E*)-1-Iodo-8-[(*tert*-butyldimethylsilyl)oxy]-1-octene (14b). Compound **14b** was prepared from **13b** by the method used for the preparation of **14d** in 54% yield: R_f 0.68 in 5% EtOAc/hexanes; IR (neat) ν 2929, 2856, 1606 (C=C), 1471, 1462, 1255 (Si–C), 1101 (Si–O–C), 836 (Si–O–C), 775 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.00 (s, 6 H, $Si(CH_3)_2$), 0.85 (s, 9 H, $SiC(CH_3)_3$), 1.20–1.50 (m, 8 H), 2.02 (m, 2 H, $CH_2CH{=}CHI$), 3.55 (t, 2 H, J = 6.4 Hz, CH_2OSi), 5.95 (dt, 1 H, J = 1.3, 14.5 Hz, CH=C*H*I), 6.46 (dt, 1 H, J = 7.2, 14.3 Hz, C*H*=CHI); ^{13}C NMR ($CDCl_3$) δ -5.46 ($Si(CH_3)_2$), 18.13 ($SiC(CH_3)_3$), 25.33, 25.76 ($SiC(CH_3)_3$), 28.13, 28.47, 32.50, 35.76, 62.91 (CH_2OSi), 74.14 (CH=*C*HI), 146.41 (*C*H=CHI); HRMS calcd for $C_{14}H_{29}OSi$ 368.1024, found 311.0320 $(M^+ - C_4H_9)^+$.

(*E*)-1-Iodo-10-[(*tert*-butyldimethylsilyl)oxy]-1-decene (14c). Compound **14c** was prepared from **13c** by the method used for the preparation of **14d** in 63% yield: R_f 0.64 in 5% EtOAc/hexanes; IR (neat) ν 3050 (C=*C*—*H*), 3000–2800, 1605 (C=C), 1460, 1253 (Si–C), 1095 (Si–O–C), 825 (Si–O–C), 765 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.05 (s, 6 H, $Si(CH_3)_2$), 0.90 (s, 9 H, $SiC(CH_3)_3$, 1.25–1.40 (m, 10 H), 1.50 (m, 2 H), 2.05 (m, 2 H, $CH_2CH{=}CHI$), 3.60 (t, 2 H, J = 6.5 Hz, CH_2OSi), 5.97 (dt, 1 H, J = 1.4, 14.3 Hz, CH=C*H*I), 6.51 (dt, 1 H, J = 7.1, 14.3 Hz, C*H*=CHI); ^{13}C NMR ($CDCl_3$) δ -5.26 ($Si(CH_3)_2$), 18.35 ($SiC(CH_3)_3$), 25.74, 25.97 ($SiC(CH_3)_3$), 28.32, 28.85, 29.31, 32.83, 36.02, 63.25 (CH_2OSi), 74.25 (CH=*C*HI), 146.74 (*C*H=CHI); HRMS calcd for $C_{16}H_{33}OSiI$ 396.1336, found 395.1270 $(M^+ - H)^+$, 339.0645 $(M^+ - C_4H_9)^+$.

(*E*)-11-(Tributylstannyl)-10-undecen-1-ol (8d). A solution of 3.076 g (7.494 mmol) of (*E*)-1-iodo-11-[(*tert*-butyldimethylsilyl)oxy]-1-undecene (**14d**) in 75 mL of ether was cooled to -78 °C, followed by the slow addition of 4.90 mL (7.64 mmol, 1.02 equiv) of a 1.56 M solution of *n*-BuLi in hexanes. After 3 h, 2.70

g (8.29 mmol, 1.11 equiv) of Bu_3SnCl was added to the mixture. The mixture was allowed to warm to 25 °C over a 3-h period and was stirred at 25 °C for 30 h. At this time, the mixture was diluted with 40 mL of water and extracted with two 50-mL portions of ether. The combined ether extracts were washed with one 50-mL portion of water and one 50-mL portion of a saturated brine solution and dried over anhydrous Na_2SO_4. The solution was filtered and concentrated in vacuo to yield a yellow oil. The crude oil was dissolved in 15 mL of THF and was cooled to 0 °C, followed by the addition of 20.0 mL (20.0 mmol, 2.67 equiv) of a 1.0 M solution of n-Bu_4NF in THF. The cold bath was removed after 1.5 h, and the mixture was stirred at 25 °C for 2 h longer. The mixture was diluted with 25 mL of water and extracted with three 25-mL portions of ether. The combined ether extracts were washed with one 20-mL portion of water and one 20-mL portion of a saturated brine solution and dried over anhydrous Na_2SO_4. Purification by reverse-phase silica gel chromatography (30 g of C_{18} silica gel, MeCN) yielded 2.682 g (77.9%) of a faint yellow oil: R_f 0.19 in 10% EtOAc/hexanes; IR (neat) ν 3365 (b, OH), 3000–2800, 1598 (C=C), 1463, 1375, 1065, 1050, 982 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.65–1.00 (m, 15 H), 1.10–1.70 (m, 27 H), 2.10 (m, 2 H, CH_2CH=CH), 3.61 (t, 2 H, J = 6.5 Hz, CH_2OH), 5.65–6.10 (m, 2 H, CH_2CH=CHSn); ^{13}C NMR ($CDCl_3$) δ 9.60, 13.52, 25.83, 27.16, 29.01, 29.12, 29.45, 29.58, 32.91, 37.80, 62.99 (CH_2OH), 127.16 (CH=CHSn), 149.79 (CH=CHSn). Anal. Calcd for $C_{23}H_{48}OSn$: C, 60.14; H, 10.53. Found: C, 60.07; H, 10.56.

(*E*)-6-(Tributylstannyl)-5-hexen-1-ol (8a). Compound **8a** was prepared by the method used for preparation of **8d** from **14a** in 98% yield: R_f 0.35 in 20% EtOAc/hexanes; IR (neat) ν 3600–3050 (b, OH), 2956, 2926, 2854, 1599 (C=C), 1457, 1376, 1070 (C–O), 990 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.87 (m, 15 H), 1.26–1.61 (3 m, 17 H), 2.20 (m, 2 H, CH_2CH=CHSn), 3.65 (m, 2 H, CH_2OH), 5.80–6.10 (m, 2 H, CH=CHSn); ^{13}C NMR ($CDCl_3$) δ 9.38, 13.69, 25.01, 27.25, 29.11, 32.23, 37.49, 62.88 (CH_2OH), 127.64 (CH=CHSn), 149.12 (CH=CHSn). Anal. Calcd for $C_{18}H_{38}OSn$: C, 55.55; H, 9.84. Found: C, 55.60; H, 9.88.

(*E*)-8-(Tributylstannyl)-7-octen-1-ol (8b). Compound **28b** was prepared by the method used for the preparation of **8d** from **14b** in 75% yield: R_f 0.26 in 15% EtOAc/hexanes; IR (neat) ν 3600–3100 (b, OH), 3000–2800, 1598 (C=C), 1464, 1376, 1072 (C–O), 989 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.87 (m, 15 H), 1.26–1.52 (m, 21 H), 2.13 (m, 2 H, CH_2CH=CHSn), 3.63 (t, 2 H, J = 6.6 Hz, CH_2OH), 5.70–6.05 (m, 2 H, CH=CHSn); ^{13}C NMR ($CDCl_3$) δ 9.34, 13.70, 25.58, 27.25, 28.82, 28.85, 29.10, 32.73, 37.77, 63.00 (CH_2OH), 127.10 (CH=CHSn), 149.59 (CH=CHSn). Anal. Calcd for $C_{20}H_{42}OSn$: C, 57.57; H, 10.15. Found: C, 57.56; H, 10.15.

(*E*)-10-(Tributylstannyl)-9-decen-1-ol (8c). Compound **8c** was prepared by the method used for the preparation of **8d** from **14c** in 75% yield: R_f 0.20 in 10% EtOAc/hexanes; IR (neat) ν 3600–3100 (b, OH), 3000–2800, 1595 (C=C), 1460, 1370, 1060 (C–O), 1045 (C–O), 1010, 977 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.70–1.00 (m, 15 H), 1.20–1.70 (m, 25 H), 2.10 (m, 2 H, CH_2CH=CHSn), 3.61 (t, 2 H, J = 6.5 Hz, CH_2OH), 5.70–6.10 (m, 2 H, CH=CHSn); ^{13}C NMR ($CDCl_3$) δ 9.55, 13.52, 25.78, 27.16, 28.96, 29.11, 29.28, 29.39, 32.86, 37.78, 62.99 (CH_2OH), 127.16 (CH=CHSn), 149.74 (CH=CHSn). Anal. Calcd for $C_{22}H_{46}OSn$: C, 59.34; H, 10.41. Found: C, 59.44; H, 10.42.

(*E*)-6-(Tributylstannyl)-5-hexen-1-yl 2-Iodobenzoate (4a). To a solution of 1.010 g (2.596 mmol) of (*E*)-6-(tributylstannyl)-5-hexen-1-ol (**8a**) in 8 mL of ether was added 0.707 g (2.85 mmol, 1.10 equiv) of 2-iodobenzoic acid, 0.588 g (2.85 mmol, 1.10 equiv) of DCC, and 0.032 g (0.26 mmol, 0.10 equiv) of DMAP. The mixture was stirred at 25 °C for 16.75 h. The mixture was then filtered through a plug of Celite and concentrated in vacuo to yield a yellow oil. Purification by silica gel chromatography (50 g of gravity gel, 5% Et_3N in hexanes) yielded 1.192 g (74.2%) of a clear oil: R_f 0.42 in 5% EtOAc/hexanes; IR (neat) ν 3000–2800, 1731 (C=O), 1598 (C=C), 1584 (C=C), 1464, 1289, 1250 (C–O), 1133 (C–O), 1016, 740 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.86 (m, 15 H), 1.29 (m, 6 H), 1.55 (m, 8 H), 1.80 (m, 2 H, CH_2CH_2O), 2.21 (m, 2 H, CH_2CH=CHSn), 4.34 (t, 2 H, J = 6.5 Hz, CH_2OC), 5.80–6.10 (m, 2 H, CH=CHSn), 7.15 (m, 1 H, ArH), 7.40 (m, 1 H, Ar H), 7.78 (dd, 1 H, J = 1.7, 7.7 Hz, Ar H), 7.99 (dd, 1 H, J = 1.1, 7.9 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 9.38, 13.72, 25.26, 27.26, 27.99, 29.11, 37.27, 65.68 (CH_2O), 93.97, 127.84 (CH=CHSn), 128.07, 130.82, 132.47, 135.50, 141.23, 148.69 (CH=CHSn), 166.66 (C=O). Anal. Calcd for $C_{25}H_{41}OISn$: C, 48.49; H, 6.67. Found: C, 48.62; H, 6.68.

(*E*)-8-(Tributylstannyl)-7-octen-1-yl 2-Iodobenzoate (4b). Compound **4b** was prepared by the method used for the preparation of **4a** from **8b** in 85% yield: R_f 0.38 in 5% EtOAc/hexanes; IR (neat) ν 3000–2800, 1731 (C=O), 1598 (C=C), 1584 (C=C), 1464, 1288, 1250 (C–O), 1133, 1100 (C–O), 1016, 741 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.88 (m, 15 H), 1.26–1.60 (m, 18 H), 1.80 (m, 2 H, CH_2CH_2OCOPh), 2.15 (m, 2 H, CH_2CH=CHSn), 4.33 (t, 2 H, J = 6.7 Hz, CH_2OCOPh), 5.80–6.05 (m, 2 H, CH=CHSn), 7.14 (m, 1 H, Ar H), 7.40 (m, 1 H, Ar H), 7.77 (dd, 1 H, J = 1.7, 7.8 Hz, Ar H), 7.98 (d, 1 H, J = 7.9 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 9.35, 13.72, 25.90, 27.24, 28.54, 28.71, 29.09, 37.73, 65.81 (CH_2OCOPh), 93.95, 127.22 (CH=CHSn), 127.83, 130.79, 132.43, 135.50, 141.21, 149.45 (CH=CHSn), 166.63 (C=O). Anal. Calcd for $C_{27}H_{45}OSnI$: C, 50.10; H, 7.01. Found: C, 50.16; H, 7.02.

(*E*)-10-(Tributylstannyl)-9-decen-1-yl 2-Iodobenzoate (4c). Compound **4c** was prepared by the method used for the preparation of **4a** from **8c** in 87% yield: R_f 0.46 in 5% EtOAc/hexanes; IR (neat) ν 3000–2800, 1731 (C=O), 1598 (C=C), 1584 (C=C), 1464, 1288, 1250 (C–O), 1133, 1100 (C–O), 1016, 740 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.87 (m, 15 H), 1.25–1.60 (m, 22 H), 1.77 (m, 2 H, CH_2CH_2OCOPh), 2.12 (m, 2 H, CH_2CH=CHSn), 4.33 (t, 2 H, J = 6.7 Hz, CH_2OCOPh), 5.80–6.10 (m, 2 H, CH=CHSn), 7.14 (m, 1 H, Ar H), 7.40 (m, 1 H, Ar H), 7.78 (dd, 1 H, J = 1.7, 7.6 Hz, Ar H), 7.90 (dd, 1 H, J = 1.1, 7.9 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 9.39, 13.72, 26.05, 27.26, 28.59, 28.88, 29.04, 29.12, 29.22, 29.38, 37.87, 65.86 (CH_2OCOPh), 93.95, 127.03 (CH=CHSn), 127.84, 130.81, 132.42, 135.60, 141.23, 149.74 (CH=CHSn), 166.67 (C=O). Anal. Calcd for $C_{29}H_{49}O_2ISn$: C, 51.58; H, 7.31. Found: C, 51.41; H, 7.38.

(*E*)-11-(Tributylstannyl)-10-undecen-1-yl 2-Iodobenzoate (4d). Compound **4d** was prepared by the method used for the preparation of **4a** from **8d** in 87% yield: R_f 0.46 in 5% EtOAc/hexanes; IR (neat) ν 3000–2800, 1730 (C=O), 1595 (C=C), 1583 (C=C), 1460, 1282, 1245 (C–O), 1127, 1092 (C–O), 1010, 728 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.83 (m, 15 H), 1.15–1.65 (m, 24 H), 1.75 (m, 2 H, CH_2CH_2OCOPh), 2.10 (m, 2 H, CH_2CH=CHSn), 4.31 (t, 2 H, J = 6.6 Hz, CH_2OCOPh), 5.80–6.10 (m, 2 H, CH=CHSn), 7.12 (m, 1 H, Ar H), 7.38 (m, 1 H, Ar H), 7.76 (dd, 1 H, J = 1.7, 7.8 Hz, Ar H), 7.96 (dd, 1 H, J = 1.0, 7.9 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 9.36, 13.69, 26.01, 27.23, 28.55, 28.87, 29.09, 29.22, 29.40, 37.85, 65.82 (CH_2OCOPh), 93.93, 126.94 (CH=CHSn), 127.80, 130.78, 132.40, 135.55, 141.20, 149.75 (CH=CHSn), 166.61 (C=O). Anal. Calcd for $C_{30}H_{51}IO_2Sn$: C, 52.27; H, 7.46. Found: C, 52.41; H, 7.51.

(*E*)-2,3-Benzo-14-tetradec-4-enolide (3d) by High Dilution. A solution containing 0.116 g (0.168 mmol) of (*E*)-11-(tributylstannyl)-10-undecen-1-yl 2-iodobenzoate (**4d**) and 0.006 g (0.005 mmol, 3 mol %) of $Pd(PPh_3)_4$ catalyst in 35 mL of toluene (4.8×10^{-3} M in substrate concentration) was heated at reflux for 5.5 h. At this time, no starting material remained as observed by TLC analysis of the mixture. The mixture was allowed to cool to 25 °C and was filtered through a plug of Celite, eluting with ether. The solvent was removed by bulb-to-bulb distillation and the residue was dissolved in 15 mL of ether. The ether solution was added to 10 mL of a half-saturated aqueous solution of KF, which was stirred for 3 h. The layers were separated and the ether extract was washed with two 10-mL portions of water and concentrated in vacuo. The residue was dissolved in hexanes, dried over anhydrous Na_2SO_4, and filtered, and the filtrate was concentrated in vacuo to yield 0.028 g (61%) of a pale yellow oil: R_f 0.41 in 5% EtOAc/hexanes; IR (neat) ν 2920, 2850, 1710 (C=O), 1595 (C=C), 1440, 1375, 1285, 1250 (C–O), 1115 (C–O), 1065, 735 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.45 (m, 12 H), 1.71 (m, 2 H, CH_2CH_2OCOPh), 2.27 (m, 2 H, CH=CHCH_2), 4.40 (m, 2 H, CH_2OCOPh), 5.99 (dt, 1 H, J = 7.4, 15.6 Hz, PhCH=CH), 7.11 (d, J = 15.6 Hz, PhCH=CH), 7.26 (m, 1 H, Ar H), 7.38–7.50 (2 m, 2 H, Ar H), 7.73 (m, 1 H, Ar H); ^{13}C NMR ($CDCl_3$) δ 24.14, 24.85, 25.35, 26.05, 27.08, 27.68, 28.88, 31.30, 65.03 (CH_2OCOPh), 126.54, 127.37, 129.38, 129.88, 130.38, 131.30, 134.57, 138.08, 169.41 (C=O); LRMS calcd for $C_{18}H_{24}O_2$ 272, found 272 (M^+). Anal. Calcd for $C_{18}H_{24}O_2$: C, 79.37; H, 8.88. Found: C, 79.23; H, 8.89.

(*E*)-2,3-Benzo-13-tridec-4-enolide (3c) by Syringe Pump. A solution of 0.0042 g (0.0036 mmol, 2.4 mol %) of $Pd(PPh_3)_4$ in 25 mL of toluene was heated to 105 °C. To this solution was

added a 2.5-mL aliquot of a solution of 0.103 g (0.152 mmol) of (*E*)-10-(tributylstannyl)-9-decen-1-yl 2-iodobenzoate (**4c**) in 10 mL of toluene. The remaining 7.5 mL of the precursor solution was added over a 5-h period via syringe pump. After 9 h, the reaction was not complete as observed by TLC, and 0.0032 g (0.0027 mmol, 1.8 mol %) more catalyst was added to the reaction mixture. After 33 h, the reaction mixture was allowed to cool to 25 °C and was filtered through a small plug of silica gel, eluting with ether. The filtrate was concentrated in vacuo, and the residue was purified by silica gel chromatography (60–200 mesh, 0–5% EtOAc in hexanes) to yield a yellow oil. Further purification of this crude product by PTLC (one 10 × 20 cm plate, 0.25 mm thickness, 0–10% methylene chloride in hexanes) afforded 0.0264 g (67.0%) of a faint yellow oil: R_f 0.33 in 5% EtOAc/hexanes; IR (neat) ν 2931, 2852, 1708 (C=O), 1598 (C=C), 1447, 1290, 1256 (C–O), 1126 (C–O), 746 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.35–1.60 (2 m, 10 H), 1.75 (m, 2 H, CH_2CH_2OCOPh), 2.30 (m, 2 H, CH_2CH=CH), 4.36 (m, 2 H, CH_2OCOPh), 5.95 (dt, 1 H, J = 7.1, 15.6 Hz, PhCH=C*H*), 6.93 (d, 1 H, J = 15.6 Hz, PhC*H*=CH), 7.27 (m, 1 H, Ar H), 7.40–7.55 (m, 2 H, Ar H), 7.85 (dd, 1 H, J = 1.3, 7.6 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 23.22, 23.88, 24.17, 26.55, 26.66, 27.18, 30.72, 65.48 (CH_2OCOPh), 126.66, 127.33, 129.45, 130.09, 130.52, 131.63, 133.23, 138.35, 169.13 (C=O). Anal. Calcd for $C_{17}H_{22}O_2$: C, 79.03; H, 8.58. Found: C, 78.78; H, 8.54.

(*E*)-2,3-Benzo-11-undec-4-enolide (3b). Compound **3b** was prepared in 37% yield from **4b** by the syringe pump method: R_f 0.27 in 5% EtOAc/hexanes; IR (neat) ν 3000–2800, 1712 (C=O), 1600 (C=C), 1449, 1289, 1257 (C–O), 1125 (C–O), 968, 765 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.55 (m, 6 H), 1.75 (m, 2 H, CH_2CH_2OCOPh), 2.30 (m, 2 H, CH_2CH=CH), 4.33 (m, 2 H, CH_2OCOPh), 5.71 (dt, 1 H, J = 7.1, 15.8 Hz, PhCH=C*H*), 6.70 (d, 1 H, J = 15.8 Hz, PhC*H*=CH), 7.28–7.33 (m, 2 H, Ar H), 7.43 (m, 1 H, Ar H), 7.75 (dd, 1 H, J = 1.3, 7.6 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 23.77, 25.42, 26.19, 26.68, 30.88, 66.05 (CH_2OCOPh), 126.56, 127.82, 129.76, 130.52, 131.46, 131.49, 132.26, 139.29, 169.50 (C=O); HRMS calcd for $C_{15}H_{18}O_2$ 230.1302, found 230.1309 (M^+).

Cyclic Dimer from Cyclization of 4a. The dimer was prepared in 65% yield by the syringe pump method: R_f 0.38 in 5% EtOAc/hexanes; IR (Nujol mull) ν 1704 (C=O), 1599 (C=C), 1294, 1261 (C–O), 1132, 1120 (C–O), 976, 744 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.68 (m, 4 H, CH_2), 1.86 (m, 4 H, CH_2), 2.32 (m, 4 H, CH_2CH=CHPh), 4.37 (t, 4 H, J = 6.5 Hz, CH_2OCOPH), 6.09 (dt, 2 H, J = 6.9, 15.6 Hz, PhCH=C*H*), 7.01 (d, 2 H, J = 15.7 Hz, PhC*H*=CH), 7.26 (m, 2 H, Ar H), 7.41 (m, 2 H, Ar H), 7.50 (m, 2 H, Ar H), 7.81 (dd, 2 H, J = 1.5, 7.9 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 25.57, 28.38, 33.15, 65.34 (CH_2OCOPh), 126.72, 126.93, 129.33, 130.53, 131.66, 132.56, 138.09, 168.78 (C=O); LRMS calcd for $C_{26}H_{28}O_4$ 404, found 404 (M^+); HRMS calcd for $C_{26}H_{28}O_4$ 404.1980, found 404.1973 (M^+).

Methyl 2-(Tributylstannyl)benzoate (16). A solution of 1.05 g (4.01 mmol) of methyl 2-iodobenzoate, 2.90 g (2.53 mL, 5.00 mmol, 1.25 equiv) of hexabutylditin, and 0.037 g (0.032 mmol, 0.80%) of $Pd(PPh_3)_4$ in 10 mL of toluene was heated at reflux for 21 h. The mixture was cooled to 25 °C, filtered through a plug of Celite, and concentrated in vacuo. The residue was dissolved in 75 mL of ether and washed with two 25-mL portions of a 10% ammonium hydroxide solution, two 25-mL portions of water, and one 25-mL portion of a saturated brine solution. The ether extract was dried over anhydrous Na_2SO_4 and filtered, and the filtrate was concentrated in vacuo. The residue was partioned between CH_3CN and hexane. The hexane extract was concentrated in vacuo and purified by silica gel chromatography (60–200 mesh, hexanes) to yield 0.710 g (41.7%) of a colorless oil: R_f 0.71 in 5% EtOAc/hexanes; IR (neat) ν 3054 (Ar*C*—*H*), 3000–2800, 1712 (C=O), 1463, 1433, 1275 (C–O), 1134, 1100 (C–O), 735 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.86 (t, 9 H, J = 7.0 Hz, $CH_3(CH_2)_3Sn$), 1.05 (m, 6 H), 1.30 (m 6 H), 1.49 (m, 6 H), 3.90 (s, 3 H, OCH_3), 7.37 (m, 1 H, Ar H), 7.48 (m, 1 H, Ar H), 7.64 (m, 1 H, Ar H), 8.09 (dd, 1 H, J = 7.6, 0.4 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 11.03, 13.69, 27.41, 29.03, 52.24 (OCH_3), 127.91, 129.78, 131.70, 135.50, 137.01, 146.95, 168.97 (C=O). Anal. Calcd for $C_{20}H_{34}O_2Sn$: C, 56.50; H, 8.06. Found: C, 56.63; H, 8.09.

2-(Tributylstannyl)benzoic Acid (17). A solution of 0.151 g (0.355 mmol) of methyl 2-(tributylstannyl)benzoate (**16**) and 0.031 g (0.74 mmol, 2.1 equiv) of $LiOH-H_2O$ in 5 mL of methanol was stirred for 7 days at 65 °C. At this time, the mixture was cooled to 25 °C. The methanol was removed in vacuo and the residue was taken up in a mixture of 10 mL of ether and 10 mL of water. The mixture was acidified to pH 2, followed by extraction with one 10-mL portion of ether. The ether extract was washed with one 10-mL portion of water and one 10-mL portion of a saturated brine solution and dried over anhydrous $MgSO_4$. After filtration and removal of the solvent, 0.134 g (91.5%) of the acid was obtained as a pale yellow oil: R_f 0.66 in 50% EtOAc/hexanes; IR (neat) ν 3400–2300 (b, C*O*O*H*), 3055 (Ar*C*–*H*), 3000–2800, 1681 (C=O), 1578, 1561, 1530, 1466, 1411, 1283, 1146, 736 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.85 (t, 9 H, J = 7.2 Hz, $CH_3(CH_2)_3Sn$), 1.07 (m, 6 H), 1.32 (m, 6 H), 1.50 (m, 6 H), 7.42 (m, 1 H, Ar H), 7.55 (m, 1 H, Ar H), 7.68 (dd, 1 H, J = 1.0, 7.2 Hz, Ar H), 8.25 (dd, 1 H, J = 1.0, 7.7 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 11.19, 13.71, 27.42, 29.20, 128.11, 130.96, 132.69, 134.31, 137.18, 148.17, 174.27 (*C*=O); HRMS calcd for $C_{19}H_{32}O_2{}^{118}Sn$ 410.1410, found 353.0714 ($M^+ - C_4H_9$)$^+$.

(*E*)-10-Iodo-9-decen-1-ol (18). A solution of 0.78 g (2.0 mmol) of (*E*)-1-iodo-10-[(*tert*-butyldimethylsilyl)oxy]-1-decene (**14c**) in 5 mL of THF was cooled to 0 °C, followed by the addition of 4.0 mL (4.0 mmol, 2.0 equiv) of a 1.0 M solution of *n*-Bu_4NF in THF. After 10 min, the cold bath was removed and the reaction was subsequently stirred at 25 °C for 2 h. The solution was concentrated in vacuo. The residue was dissolved in 30 mL of ether and washed with two 10-mL portions of water and one 10-mL portion of a saturated brine solution. The ether extract was dried over anhydrous K_2CO_3 and filtered, and the filtrate was concentrated in vacuo to yield a yellow oil. Purification by silica gel chromatography (gravity gel, 50% ether in hexanes) yielded 0.39 g (69%) of a clear oil: IR (neat) ν 3550–3100 (b, OH), 2927, 2854, 1605 (C=C), 1463, 1056 (C–O), 946 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.20–1.50 (m, 11 H), 1.58 (m, 2 H, CH_2CH_2OH), 2.05 (m, 2 H, CH_2CH=CHI), 3.64 (t, 2 H, J = 6.6 Hz, CH_2OH), 5.97 (dt, 1 H, J = 1.4, 14.3 Hz, CH=C*H*I), 6.51 (dt, 1 H, J = 7.1, 14.3 C*H*=CHI); ^{13}C NMR ($CDCl_3$) δ 25.69, 28.31, 28.81, 29.28, 32.76, 36.01, 63.04 (CH_2OH), 74.28 (CH=*C*HI), 146.74 (*C*H=CHI). This compound was carried on to **19**.

(*E*)-10-Iodo-9-decen-1-yl 2-(Tributylstannyl)benzoate (19). The ester was prepared via the DCC coupling of 2-(tributylstannyl)benzoic acid (**17**) and (*E*)-10-iodo-9-decen-1-ol (**18**) in 87% yield: R_f 0.72 in 10% EtOAc/hexanes; IR (neat) ν 3050 (C=*C*—*H*), 3000–2800, 1705 (C=O), 1463, 1267 (C–O), 1135, 1098 (C–O), 735 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.86 (t, 9 H, J = 7.2 Hz, $CH_3(CH_2)_3Sn$), 1.04 (m, 6 H), 1.20–1.60 (m, 22 H), 1.76 (m, 2 H, OCH_2CH_2), 2.04 (m, 2 H, CH_2CH=CHI), 4.30 (t, 2 H, J = 6.7 Hz, OCH_2), 5.96 (dt, 1 H, J = 1.3, 14.3 Hz, CH=C*H*I), 6.50 (dt, 1 H, J = 7.1, 14.3 Hz, C*H*=CHI), 7.37 (m, 1 H, Ar H), 7.48 (m, 1 H, Ar H), 7.62 (dd, 1 H, J = 1.1, 7.1 Hz, Ar H), 8.08 (dd, 1 H, J = 1.1, 7.6 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 11.07, 13.72, 25.98, 27.44, 28.31, 28.73, 28.84, 29.19, 36.01, 65.27 (OCH_2), 74.31 (CH=*C*HI), 127.86, 129.52, 131.60, 135.74, 136.99, 146.71, 147.19, 168.65 (*C*=O); HRMS calcd for $C_{29}H_{49}O_2I^{118}Sn$ 674.1780, found 617.1089 ($M^+ - C_4H_9$)$^+$.

(*E*)-8-(Tributylstannyl)-7-octen-1-yl 2-Hydroxybenzoate (15a). To a solution containing 0.416 g (3.01 mmol, 1.01 equiv) of salicylic acid and 0.490 mL (3.11 mmol, 0.542 g, 1.04 equiv) of DEAD in 10 mL of ether was slowly added a solution containing 1.245 g (2.991 mmol) of (*E*)-8-(tributylstannyl)-7-octen-1-ol (**8b**) and 0.789 g (3.01 mmol, 1.01 equiv) of PPh_3 in 10 mL of ether. The mixture was stirred at 25 °C for 22 h. At this time, the solution was concentrated in vacuo and the residue was purified by silica gel chromatography (60–200 mesh, 5% Et_3N in hexanes) to yield 1.423 g (88.7%) of a clear oil: R_f 0.52 in 5% EtOAc/hexanes; IR (neat) ν 3185 (b, OH), 3000–2800, 1677 (C=O), 1614 (C=C), 1486, 1464, 1301, 1251, 1213, 1157, 756 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 0.87 (m, 15H), 1.25–1.50 (m, 18 H), 1.78 (m, 2 H, OCH_2CH_2), 2.14 (m, 2 H, CH_2CH=CHSn), 4.34 (t, 2 H, J = 6.7 Hz, OCH_2), 5.80–6.05 (m, 2 H, C*H*=C*H*Sn), 6.88 (m, 1 H, Ar H), 6.97 (dd, 1 H, J = 1.0, 8.4 Hz, Ar H), 7.45 (m, 1 H, Ar H), 7.84 (dd, 1 H, J = 1.8, 7.9 Hz, Ar H), 10.86 (s, 1 H, PhO*H*); ^{13}C NMR ($CDCl_3$) δ 9.36, 13.71, 25.82, 27.26, 28.53, 28.67, 29.11, 37.72, 65.44 (OCH_2), 112.61, 117.53, 119.04, 127.32 (*C*H=CHSn), 129.82, 135.54, 149.41 (CH=*C*HSn), 161.64, 170.21 (C=O). Anal. Calcd for $C_{27}H_{46}O_3Sn$: C, 60.37; H, 8.63. Found: C, 60.50; H, 8.58.

(*E*)-10-(Tributylstannyl)-9-decen-1-yl 2-Hydroxybenzoate (15b). Compound **15b** was prepared by the method used for the

preparation of **15a** from **8c** and salicylic acid in 89% yield: R_f 0.49 in 5% EtOAc/hexanes; IR (neat) ν 3184 (b, OH), 3000–2800, 1677 (C=O), 1614 (C=C), 1486, 1465, 1394, 1302, 1251, 1213, 1157, 1089, 756 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.86 (m, 15 H), 1.20–1.60 (m, 22 H), 1.78 (m, 2 H, OCH_2CH_2), 2.12 (m, 2 H, CH_2CH=CHSn), 4.34 (t, 2 H, J = 6.7 Hz, OCH_2), 5.80–6.10 (m, 2 H, CH=CHSn), 6.87 (m, 1 H, Ar H), 6.96 (dd, 1 H, J = 1.0, 8.4 Hz, Ar H), 7.44 (m, 1 H, Ar H), 7.84 (dd, 1 H, J = 1.7, 8.0 Hz, Ar H), 10.85 (s, 1 H, PhOH); ^{13}C NMR ($CDCl_3$) δ 9.39, 13.71, 25.95, 27.26, 28.56, 28.87, 29.01, 29.12, 29.21, 29.36, 37.86, 65.48 (OCH_2), 112.65, 117.55, 119.05, 127.06 (CH=CHSn), 129.84, 135.53, 149.71 (CH=CHSn), 161.67, 170.22 (C=O). Anal. Calcd for $C_{29}H_{50}O_3Sn$: C, 61.60; H, 8.91. Found: C, 61.72; H. 8.93.

(*E*)-8-(Tributylstannyl)-7-octen-1-yl 2-[[(Trifluoromethyl)sulfonyl]oxy]benzoate (5a). To a dry flask was added 0.031 g of a 50% dispersion of NaH in oil. The dispersion was washed with three 2-mL portions of THF to remove the oil from the NaH (0.015 g, 0.65 mmol, 1.3 equiv). The NaH was dissolved in 2 mL of THF and the solution was cooled to 0 °C. A solution of 0.269 g (0.501 mmol) of (*E*)-8-(tributylstannyl)-7-octen-1-yl 2-hydroxybenzoate (**15a**) in 1 mL of THF was then added to the solution. The mixture was stirred at 0 °C for 1 h, followed by the addition of 0.285 g (0.798 mmol, 1.59 equiv) of $PhN(Tf)_2$ to the mixture. The mixture was allowed to warm to 25 °C and was stirred for an additional 20 h. The reaction mixture was concentrated in vacuo and the residue was purified by silica gel chromatography (60–200 mesh, 5% Et_3N in hexanes) to yield 0.303 g (94.9%) of a clear oil: R_f 0.30 in 5% EtOAc/hexanes; IR (neat) ν 3000–2800, 1731 (C=O), 1610 (C=C), 1429, 1294, 1249, 1211, 1144, 1075, 898 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.87 (m, 15 H), 1.25–1.55 (m, 18 H), 1.79 (m, 2 H, OCH_2CH_2), 2.13 (m, 2 H, CH_2CH=CHSn), 4.38 (t, 2 H, J = 6.9 Hz, OCH_2), 5.80–6.10 (m, 2 H, CH=CHSn), 7.30 (d, 1 H, J = 8.2 Hz, Ar H), 7.47 (m, 1 H, Ar H), 7.62 (m, 1 H, Ar H), 8.08 (dd, 1 H, J = 1.8, 7.8 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 9.34, 13.69, 25.73, 27.25, 28.38, 28.71, 29.10, 37.73, 66.23 (OCH_2), 118.70 (q, J = 320 Hz, OSO_2CF_3), 122.67, 124.85, 127.18 (CH=CHSn), 128.34, 132.64, 134.02, 148.31, 149.50 (CH=CHSn), 163.75 (C=O). Anal. Calcd for $C_{28}H_{45}O_5F_3SSn$: C, 50.24; H, 6.77. Found: C, 50.33; H, 6.80.

(*E*)-10-(Tributylstannyl)-9-decen-1-yl 2-[[(Trifluoromethyl)sulfonyl]oxy]benzoate (5b). Compound **5b** was prepared by the method used for the preparation of **5a** from **15b** in 97% yield: R_f 0.48 in 10% EtOAc/hexanes; IR (neat) ν 2956, 2926, 2854, 1731 (C=O), 1610 (C=C), 1429, 1294, 1248, 1211, 1144, 1076, 898 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.86 (m, 15 H), 1.20–1.60 (m, 22 H), 1.79 (m, 2 H, OCH_2CH_2), 2.12 (m, 2 H, CH_2CH=CH), 4.37 (t, 2 H, J = 6.9 Hz, OCH_2), 5.80–6.00 (m, 2 H, CH=CHSn), 7.30 (d, 1 H, J = 8.1 Hz, Ar H), 7.47 (m, 1 H, Ar H), 7.62 (m, 1 H, Ar H), 8.08 (dd, 1 H, J = 1.8, 7.8 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 9.37, 13.70, 25.86, 27.25, 28.40, 28.87, 29.03, 29.11, 29.20, 29.36, 37.87, 66.27 (OCH_2), 118.72 (q, J = 321 Hz, OSO_2CF_3), 122.68, 124.90, 126.98 (CH=CHSn), 128.34, 132.66, 134.01, 148.31, 149.76 (CH=CHSn), 163.77 (C=O). Anal. Calcd for $C_{30}H_{49}O_5SF_3Sn$: C, 51.66; H, 7.08. Found: C, 51.78; H, 7.09.

(*E*)-2,3-Benzo-11-undec-4-enolide (3b) from 5a. A solution of 0.056 g (0.083 mmol) of (*E*)-8-(tributylstannyl)-7-octen-1-yl 2-[[(trifluoromethyl)sulfonyl]oxy]benzoate (**5a**), 0.013 g (0.3 mmol, 3.4 equiv) of LiCl, and 0.0022 g (0.0031 mmol, 3.6 mol %) of $(PPh_3)_2PdCl_2$ in 85 mL of DMF (1.0×10^{-3} M in substrate concentration) was heated to 60 °C for 68 h. At this time, an additional 0.0020 g (0.0028 mmol, 3.4 mol %) of catalyst was added to the reaction. After 1 h longer, the mixture was cooled to 25 °C and diluted with 100 mL of ether. The mixture was washed with two 25-mL portions of water and one 25-mL portion of a saturated brine solution and dried over anhydrous $MgSO_4$. The suspension was filtered and concentrated in vacuo to yield a yellow/brown oil. Purification of the crude product by PTLC (one 10 × 20 cm plate, 10% CH_2Cl_2 in hexanes) yield 0.0043 g (22%) of a colorless oil. The product was identical with **3b** prepared from **4b**.

Methyl 2,4-Bis[(*tert*-butyldimethylsilyl)oxy]benzoate (25). A flask was charged with 3.152 g of a 50% dispersion of NaH in oil. The dispersion was washed with three 10-mL portions of THF to remove the oil from the NaH (1.58 g, 65.7 mmol, 2.20 equiv). The NaH was dissolved in 70 mL of THF and cooled to 0 °C, followed by the slow addition of a solution of 5.015 g (29.82 mmol) of methyl 2,4-dihydroxybenzoate (**24**) in 10 mL of THF to the mixture. After 25 min at 0 °C, an additional 40-mL portion of THF was added to the mixture, and the cold bath was removed. The reaction mixture was stirred at 25 °C for 30 min and was then recooled to 0 °C. At this time, 10.748 g (71.31 mmol, 2.391 equiv) of TBDMSCl was added to the mixture. The solution was allowed to warm to 25 °C over a 1-h period and was stirred at 25 °C for an additional 12 h. The mixture was poured into 50 mL of water and extracted with three 50-mL portions of ether. The combined ether extracts were dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo to yield a yellow oil. Purification by flash silica gel chromatography (120 g flash gel, 5% EtOAc in hexanes) yielded 11.703 g (98.9%) of a clear oil: R_f 0.61 in 20% EtOAc/hexanes; IR (neat) ν 3000–2800, 1731 (C=O), 1709 (C=O), 1600 (C=C), 1493, 1256 (Si–C, C–O), 1192 (C–O), 1131 (C–O), 1087 (C–O), 1003, 899, 836, 782 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.21 (s, 6 H, $Si(CH_3)_2$), 0.22 (s, 6 H, $Si(CH_3)_2$), 0.97 (s, 9 H, $SiC(CH_3)_3$), 1.01 (s, 9 H, $SiC(CH_3)_3$), 3.83 (s, 3 H, OCH_3), 6.33 (d, 1 H, J = 2.3 Hz, Ar H), 6.47 (dd, 1 H, J = 8.6, 2.3 Hz, Ar H), 7.73 (d, 1 H, J = 8.6 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ −4.39 ($SiCH_3$), 18.24 ($SiCCH_3$), 18.28 ($SiCCH_3$), 25.58 ($SiCCH_3$), 25.66 ($SiCCH_3$), 51.47 (OCH_3), 112.59, 113.41, 115.82, 133.20, 156.97, 160.12, 166.79 (C=O). Anal. Calcd for $C_{20}H_{36}O_4Si_2$: C, 60.56; H, 9.15. Found: C, 60.56; H, 9.19.

***N*,*N*-Diethyl-2,4-bis[(*tert*-butyldimethylsilyl)oxy]benzamide (26).** A solution of 40.0 mL (80.0 mmol, 4.00 equiv) of a 2.0 M solution of Me_3Al in toluene and 80 mL of toluene was cooled to −6 °C, followed by the addition of 5.87 g (8.30 mL, 80.3 mmol, 4.02 equiv) of Et_2NH. After 10 min, the cold bath was removed and the mixture was stirred for 50 min at 25 °C. At this time, a solution of 7.932 g (19.99 mmol) of methyl 2,4-bis[(*tert*-butyldimethylsilyl)oxy]benzoate (**25**) in 10 mL of toluene was added to the mixture. The reaction was heated at reflux for 16 h. The mixture was cooled to 0 °C, followed by the cautious addition of 75 mL of a 10% HCl solution. After the addition was complete, another 50-mL portion of a 10% HCl solution was added to the mixture, and the layers were separated. The organic layer was washed with one 50-mL portion of a 10% HCl solution. The combined aqueous extracts were extracted with two 100-mL portions of EtOAc. The combined organic extracts were washed with one 150-mL portion of a saturated brine solution and dried over anhydrous $MgSO_4$. The dried extracts were filtered and the filtrate was concentrated in vacuo to yield a yellow oil. Purification by flash silica gel chromatography (140 g of flash gel, 5–20% EtOAc in hexanes) yielded 8.280 g (94.6%) of a clear oil: R_f 0.38 in 20% EtOAc/hexanes; IR (neat) ν 3000–2800, 1634 (C=O), 1603, 1504, 1472, 1413, 1305, 1254, 1175, 1116, 1086, 999, 903, 832, 783 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.20 (s, 12 H, $Si(CH_3)_2$), 0.97 (m, 21 H, $SiC(CH_3)_3$, NCH_2CH_3), 1.23 (t, 3 H, J = 7.1 Hz, NCH_2CH_3), 3.00–3.80 (bm, 4 H, NCH_2), 6.31 (d, 1 H, J = 2.2 Hz, Ar H), 6.47 (dd, 1 H, J = 8.2, 2.2 Hz, Ar H), 7.05 (d, 1 H, J = 8.3 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ −4.44 ($SiCH_3$), 13.21 (NCH_2CH_3), 14.06 (NCH_2CH_3), 18.09 ($SiCCH_3$), 18.17 ($SiCCH_3$), 25.58 ($SiCCH_3$), 25.61 ($SiCCH_3$), 39.22 (NCH_2), 42.80 (NCH_2), 111.26, 113.40, 123.21, 128.42, 152.08, 156.66, 169.13 (C=O). Anal. Calcd for $C_{23}H_{43}O_3NSi_2$: C, 63.10; H, 9.90. Found: C, 63.01; H, 9.91.

***N*,*N*-Diethyl-4,6-bis[(*tert*-butyldimethylsilyl)oxy]-2-iodobenzamide (27).** A solution of 1.724 g (3.938 mmol) of *N*,*N*-diethyl-2,4-bis[(*tert*-butyldimethylsilyl)oxy]benzamide (**26**) in 15 mL of ether was cooled to −78 °C, followed by the slow addition of 2.45 mL (4.16 mmol, 1.06 equiv) of a 1.7 M solution of *t*-BuLi in pentane. The solution turned yellow and then faded to a pale yellow. The mixture was allowed to warm to −40 °C over a 1-h period and was kept between −45 °C and −40 °C for 30 min longer. The solution was recooled to −78 °C, followed by the addition of 0.736 g (0.230 mL, 4.53 mmol, 1.15 equiv) of ICl. The cold bath was removed and upon reaching 25 °C the solution was diluted with 50 mL of ether. The solution was washed with two 20-mL portions of a 20% solution of $NaHSO_3$ and two 20-mL portions of a saturated $NaHCO_3$ solution (added slowly). The organic extract was dried over anhydrous $MgSO_4$ and filtered, and the filtrate was concentrated in vacuo to yield a dark oil. The crude product was purified by flash silica gel chromatography (50 g of flash gel, 5–7% EtOAc in hexanes) to yield 1.560 g (70.2%) of a viscous oil, which upon standing became a white cube-like crystalline solid (mp 59.5–61.5 °C): R_f 0.46 in 20% EtOAc/

hexanes; IR (neat) ν 3000–2850, 1643 (C=O), 1588, 1547, 1423, 1256 (Si–C), 1147 (C–O), 1021, 908, 829, 783 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.21 (m, 12 H, $SiCH_3$), 0.94 (s, 9 H, $SiCCH_3$), 0.97 (s, 9 H, $SiCCH_3$), 1.09 (t, 3 H, J = 7.2 Hz, NCH_2CH_3), 1.26 (t, 3 H, J = 7.1 Hz, NCH_2CH_3), 3.15 (m, 2 H, NCH_2), 3.25 (m, 1 H, NCH_2), 3.77 (m, 1 H, NCH_2), 6.29 (d, 1 H, J = 2.1 Hz, Ar H), 6.93 (d, 1 H, J = 2.1 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ −4.68 ($SiCH_3$), −4.52 ($SiCH_3$), −4.46 ($SiCH_3$), −4.09 ($SiCH_3$), 12.67 (NCH_2CH_3), 13.87 (NCH_2CH_3), 18.04 ($SiCCH_3$), 18.16 ($SiCCH_3$), 25.47 ($SiCCH_3$), 25.55 ($SiCCH_3$), 39.24 (NCH_2), 43.07 (NCH_2), 93.71, 111.07, 123.82, 128.66, 152.39, 156.38, 168.02 (C=O). Anal. Calcd for $C_{23}H_{42}O_3NSi_2I$: C, 49.01; H, 7.51. Found: C, 49.28; H, 7.63.

Methyl 4,6-Dihydroxy-2-iodobenzoate (28). To a solution of 0.561 g (3.79 mmol, 1.01 equiv) of Me_3OBF_4 (Lancaster Synthesis) in 10 mL of CH_2Cl_2 at 25 °C was added 1.945 g (3.450 mmol) of *N,N*-diethyl-4,6-bis[(*tert*-butyldimethylsilyl)oxy]-2-iodobenzamide (**27**) in 4 mL of CH_2Cl_2. The mixture was stirred for 7.5 h and was then concentrated in vacuo to yield a yellow oil. The oil was dissolved in 20 mL of a 1:1 solution of MeOH and a saturated Na_2CO_3 solution. The mixture was stirred for 12 h at 25 °C, followed by extraction with one 50-mL portion of ether. The aqueous layer was acidified to pH 2 with a 10% HCl solution. The acidified solution was extracted with two 100-mL portions of ether, and the extracts were dried over anhydrous $MgSO_4$. The mixture was filtered and the filtrate was concentrated in vacuo to yield an off-white solid. The solid was dissolved in a 1:1 solution of EtOAc and hexanes and then filtered through a plug of silica gel to yield 0.460 g (45.4%) of a white solid. The first organic extract was concentrated in vacuo to yield 0.345 g (34.0%) of additional product. The overall yield was 79.4% (mp 143–149 °C with dec): R_f 0.50 in 50% EtOAc/hexanes; IR (Nujol mull) ν 3300 (b, OH), 1630 (C=O), 1580, 1439, 1329, 1264 (C–O), 1185, 1159, 943, 793; ^1H NMR ($CDCl_3$) δ 3.95 (s, 3 H, OCH_3), 5.25 (s, 1 H, O*H*), 6.42 (d, 1 H, J = 2.4 Hz, Ar H), 7.16 (d, 1 H, J = 2.4 Hz, Ar H), 11.46 (s, 1 H, O*H*); ^{13}C NMR (acetone-d_6) δ 52.06 (OCH_3), 95.03, 104.07, 112.46, 122.51, 162.71, 163.14, 169.45 (C=O). Anal. Calcd for $C_8H_7O_4I$: C, 32.68; H, 2.40. Found: C, 32.86; H, 2.43.

Methyl 4,6-Bis[[(2-methoxyethoxy)methyl]oxy]-2-iodobenzoate (29). A suspension of NaH/oil dispersion (0.332 g, 50% NaH by weight, 0.166 g of NaH, 6.92 mmol, 2.26 equiv) was washed with two 5-mL portions of THF, diluted with 15 mL of THF, and cooled to 0 °C. A solution of 0.892 g (3.06 mmol) of methyl 4,6-dihydroxy-2-iodobenzoate (**28**) in 5 mL of THF was cautiously added to the suspension. After 30 min, the cold bath was removed and the reaction was stirred for 2.5 h at 25 °C. At this time, the purple suspension was cooled to 0 °C, followed by the addition of 0.862 g (0.790 mL, 6.92 mmol, 2.26 equiv) of MEMCl to the suspension. After 1.5 h, the cold bath was removed and the mixture was subsequently stirred at 25 °C for 21.5 h. The solution was diluted with 20 mL of water and extracted with two 50-mL portions of ether. The combined ether extracts were washed with 25 mL of a saturated brine solution, dried over anhydrous $MgSO_4$, and filtered and the filtrate was concentrated in vacuo to yield a dark yellow oil. Purification by flash silica gel chromatography (60 g flash Si gel, 20–50% EtOAc in hexanes) yielded 0.920 g (63.9%) of a faint yellow oil: R_f 0.31 in 50% EtOAc/hexanes; IR (neat) ν 3000–2800, 1734 (C=O), 1595 (C=C), 1268 (C–O), 1109 (C–O), 1015 (C–O), 984 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.37 (s, 3 H, CH_3OCH_2), 3.39 (s, 3 H, CH_3OCH_2), 3.55 (m, 4 H, CH_3OCH_2), 3.79 (m, 4 H, CH_2CH_2O), 3.92 (s, 3 H, $COOCH_3$), 5.23 (s, 2 H, OCH_2O), 5.24 (s, 2 H, OCH_2O), 6.86 (d, 1 H, J = 2.1 Hz, Ar H), 7.19 (d, 1 H, J = 2.1 Ar H); ^{13}C NMR ($CDCl_3$) δ 52.66 ($COOCH_3$), 58.98 (CH_3OCH_2), 59.04 (CH_3OCH_2), 67.92 (CH_3OCH_2), 67.98 (CH_3OCH_2), 71.39 (CH_2CH_2O), 71.43 (CH_2CH_2O), 92.14, 93.36 (OCH_2O), 93.74 (OCH_2O), 103.85, 119.44, 125.09, 155.04, 158.91, 167.74 (C=O). Anal. Calcd: C, 40.87; H, 4.93. Found: C, 40.96; H, 4.94.

4,6-Bis[[(2-methoxyethoxy)methyl]oxy]-2-iodobenzoic Acid (30). A solution of 0.103 g (0.218 mmol) of methyl 4,6-bis[[(2-methoxyethoxy)methyl]oxy]-2-iodobenzoate (**29**) and 0.096 g (2.3 mmol, 10 equiv) of $LiOH-H_2O$ in 6 mL of a 2:1:1 mixture of THF, methanol, and water was heated to 75 °C for 65 h. The mixture was cooled to 25 °C and partitioned with 10 mL of ether and 20 mL of water. The aqueous layer was acidified to pH 3 and extracted with one 30-mL portion of ether. The ether extract was acidified to pH 3 and extracted with one 30-mL portion of ether. The ether extract was dried over anhydrous $MgSO_4$ and filtered, and the filtrate was concentrated in vacuo to yield 0.086 g (86%) of a faint yellow oil: R_f 0.47 in ethanol; IR (neat) ν 3600–2300 (b, COO*H*), 3000–2800, 1731 (C=O), 1596 (C=C), 1454, 1264 (C–O), 1158 (C–O), 1108 (C–O), 1014 (C–O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.31 (s, 3 H, OCH_3), 3.40 (s, 3 H, OCH_3), 3.55 (m, 4 H, CH_3OCH_2), 3.83 (m, 4 H, CH_2CH_2O), 5.25 (s, 2 H, OCH_2O), 5.28 (s, 2 H, OCH_2O), 6.85 (d, 1 H, J = 2.1 Hz, Ar H), 7.24 (d, 1 H, J = 2.1 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 58.94 (OCH_3), 59.05 (OCH_3), 67.98 (CH_3OCH_2), 68.31 (CH_3OCH_2), 71.46 (CH_2CH_2O), 71.68 (CH_2CH_2O), 92.37, 93.40, 103.65, 120.16, 124.26, 154.87, 159.12, 169.42 (C=O). Anal. Calcd for $C_{15}H_{21}O_8I$: C, 39.49; H, 4.64. Found: C, 39.62; H, 4.67.

(*R*)-4-Penten-2-ol (32). To a suspension of 1.643 g (8.627 mmol, 0.151 equiv) of CuI in 40 mL of THF at −30 °C was slowly added 86.0 mL (86.0 mmol, 1.50 equiv) of a solution of 1.0 M vinylmagnesium bromide in THF. After 5 min, a solution of 3.32 g (4.00 mL, 57.2 mmol) of (*R*)-propylene oxide (**31**) in 5.0 mL of THF was added to the mixture. The mixture was warmed to −10 °C and placed in a freezer at 0 °C for 12 h. The mixture was stirred at 0 °C for 1 h longer and then poured into a solution of 100 mL of saturated aqueous NH_4Cl and 75 g of ice. The mixture was stirred for 3 h and extracted with three 100-mL portions of ether, and the combined organic extracts were dried over anhydrous $MgSO_4$. The extracts were filtered and the filtrate was concentrated at 0 °C by rotary evaporation at 15 mmHg. The resulting brown oil was distilled under reduced pressure to yield 2.313 g (47.0%) of a clear distillate (bp 30–35 °C, 8 mmHg; lit. bp 115 °C, 746 mmHg[36b]): R_f 0.30 in 20% EtOAc/hexanes. The ^1H NMR spectrum was consistent with the published data.[36a] $[\alpha]^{27}_D$ −8.4° (c = 9.46 in ether) lit.[36b] $[\alpha]^{20}_D$ −9.08° (c = 9.18 ether).

(*R*)-4-[(*tert*-Butyldimethylsilyl)oxy]-1-pentene. A solution of 2.313 g (26.85 mmol) of (*R*)-4-penten-2-ol (**32**), 0.544 g (7.50 mL, 53.8 mmol, 2.00 equiv) of Et_3N, and 0.325 g (2.66 mmol, 9.91 mol %) of DMAP in 50 mL of CH_2Cl_2 was cooled to 0 °C, followed by the addition of 5.272 g (34.98 mmol, 1.303 equiv) of TBDMSCl. The mixture was allowed to warm to 25 °C and was stirred for 17 h. The mixture was diluted with 50 mL of water, and the layers were partitioned. The aqueous layer was extracted with one 50-mL portion of CH_2Cl_2, and the combined organic layers were washed with two 50-mL portions of a saturated $CuSO_4$ solution and one 50-mL portion of water. The organic layer was dried over anhydrous $MgSO_4$ and filtered, and the filtrate was concentrated in vacuo to yield a yellow oil. Purification by flash silica gel chromatography (30 g of flash gel, hexanes) yielded 4.147 g (77.1%) of a clear oil: R_f 0.72 in 5% EtOAc/hexanes; IR (neat) ν 3078 (C=C*H*), 3000–2800, 1642 (C=C), 1473, 1256 (Si–C), 1129, 1092 (C–O), 1046, 1005 (C–O), 836, 775 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.05 (s, 6 H, $SiCH_3$), 0.89 (s, 9 H, $SiCCH_3$), 1.13 (d, 3 H, J = 6.1 Hz, $CHCH_3$), 2.15 (m, 2 H, CH_2C=C), 3.83 (h, 1 H, J = 6.1 Hz, OC*H*), 4.95–5.10 (m, 2 H, C=CH_2), 5.82 (m, 1 H, CH=CH_2); ^{13}C NMR ($CDCl_3$) δ −4.71 ($SiCH_3$), −4.52 ($SiCH_3$), 18.16 ($SiCCH_3$), 23.41 (CCH_3), 25.88 ($SiCCH_3$), 44.28 (CH_2C=C), 68.42 (OCH), 116.51 (CH_2C=CH_2), 135.64 (CH_2C=CH_2). Anal. Calcd for $C_{11}H_{24}OSi$: C, 65.93; H, 12.07. Found: C, 65.97; H, 12.05.

(*R*)-4-[(*tert*-Butyldimethylsilyl)oxy]-1-pentanol (33). To a solution of 2.489 g (12.42 mmol) of (*R*)-4-[(*tert*-butyldimethylsilyl)oxy]-1-pentene in 10 mL of THF at 25 °C was added 27.3 mL (13.6 mmol, 1.09 equiv) of a 0.5 M solution of 9-BBN in THF. The solution was stirred for 19 h at 25 °C and then cooled to 0 °C. At this time, 12.5 mL of a 15% NaOH solution and 21.0 mL of a 30% H_2O_2 solution was added to the mixture. The cold bath was removed after 30 min and the solution was stirred for 10 h at 25 °C. The mixture was extracted with two 100-mL portions of ether, and the combined extracts were dried over anhydrous $MgSO_4$. The dried extracts were filtered, and the filtrate was concentrated in vacuo to yield a clear oil. Purification by flash silica gel chromatography (80 g of flash gel, 0–20% EtOAc in hexanes) yielded 2.651 g (98.2%) of a clear oil: R_f 0.32 in 20% EtOAc/hexanes; $[\alpha]^{27}_D$ −13.26° (c = 10.05 in $CHCl_3$); IR (neat) ν 3342 (b, OH), 3000–2800, 1472, 1374, 1255 (Si–C), 1054 (C–O), 836, 774 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.07 (s, 6 H, $SiCH_3$), 0.89 (s, 9 H, $SiCCH_3$), 1.16 (d, 3 H, J = 6.1 Hz, $SiOCHCH_3$), 1.54 (m, 2 H), 1.64 (m, 2 H), 2.12 (bs, 1 H, O*H*), 3.63 (m, 2 H, CH_2OH), 3.89 (m, 1 H, SiOC*H*); ^{13}C NMR ($CDCl_3$) δ −4.80 ($SiCH_3$), −4.49 (Si-

CH_3), 18.11 (SiCCH_3), 23.25 (CHCH_3), 25.85 (SiCCH_3), 28.53, 35.98, 63.11 (HOCH_2), 68.36 (SiOCH). Anal. Calcd for $C_{11}H_{26}O_2Si$: C, 60.49; H, 12.00. Found: C, 60.55; H, 12.01.

(*R*)-4-[(*tert*-Butyldimethylsilyl)oxy]-1-bromopentane (22). A solution of 2.636 g (12.12 mmol) of (*R*)-4-[(*tert*-butyldimethylsilyl)oxy]-1-pentanol (**33**) was cooled to 0 °C, followed by the addition of 16.77 g (121.4 mmol, 10.01 equiv) of K_2CO_3, 6.067 g (18.29 mmol, 1.509 equiv) of CBr_4, and 9.578 g (36.52 mmol, 3.012 equiv) of PPh_3. After 30 min, the cold mixture was filtered through a plug of silica gel, eluting with 120 mL of hexanes. The orange solution was refiltered through another plug of silica gel to remove all color. The solution was concentrated in vacuo to yield 3.229 g (95.0%) of a clear oil (bp 68–70 °C, 0.55 mmHg): R_f 0.69 in 5% EtOAc/hexanes); $[\alpha]^{25}_D$ −8.93° (*c* = 8.92 in $CHCl_3$); IR (neat) ν 2957, 2930, 2857, 1472, 1462, 1374, 1254 (Si–C), 1132, 1090 (C–O), 1004 (C–O), 836, 774 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.05 (2 s, 6 H, SiCH_3), 0.88 (s, 9 H, SiCCH_3), 1.14 (d, 3 H, *J* = 6.1 Hz, OCHCH_3), 1.55 (m, 2 H), 1.90 (m, 2 H), 3.42 (t, 2 H, *J* = 6.8 Hz, CH_2Br), 3.83 (m, 1 H, OC*H*); ^{13}C NMR ($CDCl_3$) δ −4.78 (SiCH_3), −4.37 (SiCH_3), 18.07 (SiCCH$_3$), 23.78 (CHCH_3), 25.85 (SiCCH_3), 29.12, 34.20, 38.03, 67.78 (SiOCH). Anal. Calcd for $C_{11}H_{26}OBrSi$: C, 46.97; H, 8.96. Found: C, 47.11; H, 8.95.

(*E*)-6-(Tributylstannyl)-5-hexenal (23). A solution of 0.757 g (5.67 mmol, 2.21 equiv) of NCS in 15 mL of toluene was cooled to 0 °C, followed by the addition of 0.38 g (0.45 mL, 6.1 mmol, 2.4 equiv) of DMS to the mixture. After 5 min, the solution was cooled to −25 °C, followed by the dropwise addition of 0.999 g (2.57 mmol) of (*E*)-6-(tributylstannyl)-5-hexen-1-ol (**8a**) in 2.5 mL of toluene to the reaction mixture. The reaction was kept at −20 °C for 4.25 h, followed by the addition of 0.62 g (0.86 mL, 6.1 mmol, 2.4 equiv) of Et_3N. The cold bath was removed and after 5 min, the white suspension was diluted with 25 mL of ether. The mixture was washed with one 50-mL portion of a 1% HCl solution, dried over anhydrous $MgSO_4$, filtered, and concentrated in vacuo to yield a yellow oil. Purification by flash chromatography (100 g of flash gel, 2% Et_3N in hexanes) yielded 0.850 g (85.4%) of a faint yellow oil: IR (neat) ν 3000–2800, 2709 (*H*—*C*=O), 1728 (C=O), 1689, 1598 (C=C), 1463, 1375, 1069, 988 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.89 (m, 15 H), 1.31 (m, 6 H), 1.50 (m, 6 H), 1.75 (m, 2 H), 2.17 (m, 2 H, CH_2C=CSn), 2.43 (dt, 2 H, *J* = 1.7, 7.4 Hz, CH_2C=O), 5.90 (m, 2 H, C*H*=C*H*Sn), 9.78 (t, 1 H, *J* = 1.6 Hz, *H*C=O); ^{13}C NMR ($CDCl_3$) δ 9.41, 13.70, 21.20, 27.25, 29.11, 36.97, 43.18, 129.08 (*C*H=CHSn), 147.85 (CH=*C*HSn), 202,57 (*C*=O). This compound was carried on to **34**.

(10*R*)-(*E*)-1-(Tributylstannyl)-10-[(*tert*-butyldimethylsilyl)oxy]-1-undecen-6-ol (34). To a solution of 0.092 g (3.8 mmol, 2.2 equiv) of Mg metal in 7.5 mL of ether in a three-neck flask equipped with a dropping funnel and reflux condenser was added 25% of a solution of 0.948 g (3.38 mmol, 2.00 equiv) of (*R*)-4-[(*tert*-butyldimethylsilyl)oxy]-1-bromopentane (**22**) in 5 mL of ether. The solution was heated to reflux, followed by the addition of 0.011 g (0.005 mL, 0.059 mmol, 1.6 mol % based on Mg metal) of 1,2-dibromoethane. The solution became slightly cloudy. The cloudy solution was kept at reflux and the remainder of the bromide solution was added to the mixture over 45 min. The solution was kept at reflux for 24 h, cooled to 25 °C, and added to a solution of 0.656 g (1.69 mmol) of (*E*)-6-(tributylstannyl)-5-hexenal (**23**) in 10 mL of ether at 25 °C. The solution was stirred at 25 °C for 17.5 h. At this time, 20 mL of a saturated aqueous solution of NH_4Cl was carefully added to quench the reaction. After stirring for 45 min, the mixture was extracted with two 50-mL portions of ether. The combined extracts were dried over anhydrous $MgSO_4$ and filtered, and the filtrate was concentrated in vacuo to yield an oil. The crude product was purified by flash silica gel chromatography (50 g of flash gel, 5% Et_3N in hexanes) to yield 0.718 g (72.7%) of a faint yellow oil: R_f 0.25 in 5% EtOAc/hexanes; $[\alpha]^{25}_D$ −4.75° (*c* = 3.66 in $CHCl_3$); IR (neat) ν 3362 (b, OH), 2955, 2927, 2856, 1598 (C=C), 1462, 1376, 1254 (Si–C), 1135, 1071 (C–O), 990 (C–O), 835, 774 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.05 (s, 6 H, Si(CH_3)$_2$), 0.87 (m, 24 H), 1.12 (d, 3 H, *J* = 6.1 Hz, SiOCHCH_3), 1.26–1.57 (m, 23 H), 2.14 (m, 2 H, CH_2CH=CHSn), 3.78 (bs, 1 H, CHO*H*), 3.79 (m, 1 H, SiOC*H*), 5.91 (m, 2 H, C*H*=C*H*Sn); ^{13}C NMR ($CDCl_3$) δ −4.69 (SiCH_3), −4.39 (SiCH_3), 9.37, 13.71, 18.14 (SiCCH$_3$), 21.73, 23.78, 24.91, 25.90 (SiCCH_3), 27.26, 29.11, 36.94, 37.48, 37.57, 37.79, 39.70, 68.54 (SiOCH), 71.79 (*C*HOH), 127.55 (*C*H=CHSn), 149.23 (CH=*C*-HSn). Anal. Calcd for $C_{29}H_{62}O_2SiSn$: C, 59.08; H, 10.60. Found: C, 59.16; H, 10.62.

(*R*)-(*E*)-11-(Tributylstannyl)-6-oxo-10-undecen-2-ol (35). To a solution of 0.363 g (2.72 mmol, 2.21 equiv) of NCS in 7.5 mL of toluene at 0 °C was added 0.182 g (0.215 mL, 2.93 mmol, 2.38 equiv) of DMS. After 5 min, the mixture was cooled to −22 °C, followed by the addition of 0.728 g (1.23 mmol) of (10*R*)-*E*-1-(tributylstannyl)-10-[(*tert*-butyldimethylsilyl)oxy]-1-undecen-6-ol (**34**) in 2.0 mL of toluene. The mixture was stirred at −20 °C for 3 h, followed by the addition of 0.305 g (0.420 mL, 3.01 mmol, 2.45 equiv) of Et_3N. After 5 min, the mixture was allowed to warm to 25 °C and was diluted with 20 mL of ether. The solution was washed with one 10-mL portion of an ice-cold 1% HCl solution. The solution was dried over anhydrous $MgSO_4$ and filtered, and the filtrate was concentrated in vacuo to yield a yellow oil with some solid. Purification by flash silica gel chromatography (25 g of flash gel, 5% Et_3N in hexanes) yielded a yellow oil. The oil was dissolved in 7.5 mL of THF and was cooled to 0 °C, followed by the addition of 3.10 mL (3.10 mmol, 2.52 equiv) of a 1.0 M solution of *n*-Bu_4NF in THF. The mixture was allowed to warm to 25 °C over a 1-h period and was subsequently stirred for 16 h. At this time, the solution was diluted with 30 mL of ether. The solution was washed with one 20-mL portion of water. The aqueous layer was extracted with one 25-mL portion of ether, and the combined organic extracts were washed with one 25-mL portion of a saturated brine solution and were dried over anhydrous $MgSO_4$. The solution was filtered and the filtrate was concentrated in vacuo to yield a yellow oil. Purification by flash silica gel chromatography (50 g of flash gel, 5% Et_3N in hexanes) yielded 0.468 g (79.9%) of a clear oil. The product consisted of mixture of ~6:1 of the desired product and what appeared to be the lactol as a minor product: R_f 0.26 in 20% EtOAc/hexanes; IR (neat) ν 3600–3100 (b, OH), 3000–2800, 1713 (C=O), 1598 (C=C), 1457, 1376, 1084 (C–O), 991 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.87 (m, 15 H), 1.18 (d, 3 H, *J* = 6.2 Hz, HOCHCH_3), 1.31 (m, 6 H), 1.47 (m, 6 H), 1.66 (m, 7 H), 2.13 (m, 2 H, CH_2CH=CH), 2.42 (m, 4 H, CH_2COCH_2), 3.75 (m, 1 H, HOC*H*), 5.89 (m, 2 H, C*H*=C*H*Sn); ^{13}C NMR ($CDCl_3$) δ 9.40, 13.71, 19.69, 22.86, 23.48, 27.26, 29.12, 37.13, 38.71, 41.98, 42.56, 67.58 (HOCH), 128.54 (*C*H=CHSn), 148.33 (CH=*C*HSn), 211.23 (C=O). Anal. Calcd for $C_{23}H_{46}O_2Sn$: C, 58.37; H, 9.80. Found: C, 58.25; H, 9.86.

(*S*)-(*E*)-11-(Tributylstannyl)-6-oxo-10-undecen-2-yl 4,6-Bis[[(2-methoxyethoxy)methyl]oxy]-2-iodobenzoate (36). To a solution of 0.025 g (0.054 mmol, 1.0 equiv) of 4,6-bis[[(2-methoxyethoxy)methyl]oxy]-2-iodobenzoic acid (**30**), 0.026 g (0.056 mmol, 1.0 equiv) of (*R*)-(*E*)-11-(tributylstannyl)-6-oxo-10-undecen-2-ol (**35**), and 0.014 g (0.054 mmol, 1.0 equiv) of PPh_3 in 1 mL of ether was added 0.010 g (0.0092 mL, 0.057 mmol, 1.1 equiv) of DEAD. The mixture was stirred at 25 °C for 17.5 h. At this time, the mixture was concentrated in vacuo. The residue was dissolved in $CHCl_3$ and applied to four 10 × 20 cm TLC plates. The plates were eluted three times with 30% EtOAc in hexanes, and the largest band was extracted to yield 0.045 g (91%) of a clear oil: R_f 0.39 in 50% EtOAc/hexanes; $[\alpha]^{25}_D$ +7.35° (*c* = 0.98 in $CHCl_3$; IR (neat) ν 3000–2800, 1729 (C=O), 1597 (C=C), 1562, 1457, 1269 (C–O), 1110 (C–O), 1017 (C–O), 989 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.87 (m, 15 H), 1.32 (m, 9 H), 1.46 (m, 6 H), 1.60 (m, 6 H), 2.12 (m, 2 H, CH_2CH=CHSn), 2.37–2.50 (m, 4 H, CH_2COCH_2), 3.36 (s, 3 H, OCH_3), 3.39 (s, 3 H, OCH_3), 3.54 (m, 4 H, $CH_3OCH_2CH_2$), 3.78 (m, 4 H, CH_2OCH$_2$OPh), 5.15 (m, 1 H, COOC*H*CH$_3$), 5.22 (s, 2 H, PhOCH_2), 5.23 (s, 2 H, PhOCH_2), 5.89 (m, 2 H, C*H*=C*H*Sn), 6.86 (d, 1 H, *J* = 2.1 Hz, Ar H), 7.17 (d, 1 H, *J* = 2.1 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 9.37, 13.68, 19.51, 19.92, 22.85, 27.22, 29.08, 35.26, 37.12, 42.06, 42.26, 58.93 (OCH_3), 59.02 (OCH_3), 67.89 (CH_3OCH_2), 67.94 (CH_3OCH_2), 71.40 (C-H_2CH_2O), 71.45 (CH_2CH_2O), 72.09 (COO*C*H), 91.73, 93.39 (O*C*H$_2$OPh), 93.62 (OCH$_2$OPh), 103.78, 119.35, 125.46, 128.47 (*C*H=CHSn), 148.28 (CH=*C*HSn), 154.86, 158.74, 166.94, 210.48 (*C*=O). Anal. Calcd for $C_{38}H_{65}O_9ISn$: C, 50.09; H, 7.15. Found: C, 50.15; H, 7.24.

(*S*)-2,4-Bis[(2-methoxyethoxy)methyl]zearalenone (37) (High Dilution Conditions). A solution of 0.045 g (0.049 mmol) of (*S*)-(*E*)-11-(tributylstannyl)-6-oxo-10-undecen-2-yl 4,6-bis-[[(2-methoxyethoxy)methyl]oxy]-2-iodobenzoate (**36**) and 0.0015 g (0.0013 mmol, 2.6 mol %) of $Pd(PPh_3)_4$ in 50 mL of toluene (1 × 10^{-3} M in substrate concentration) was heated at reflux for 19

h. The mixture was cooled to 0 °C and the solvent was removed by bulb-to-bulb distillation. The residue was purified by PTLC (two 10 × 20 cm plates, eluted two times with 30% EtOAc in hexanes) and the largest UV-active band was extracted to yield 0.0073 g (30%) of a clear oil: R_f 0.23 in 50% EtOAc/hexanes; $[\alpha]^{25}_D$ +39.0° (c = 0.39 in $CHCl_3$); IR (neat) ν 3000–2800, 1720 (C=O), 1600 (C=C), 1578, 1450, 1264 (C–O), 1108 (C–O), 1020 (C–O) cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.32 (d, 3 H, J = 6.3 Hz, $COOCHCH_3$), 1.45–1.90 (m, 6 H), 2.10 (m, 3 H), 2.35 (m, 2 H), 2.70 (m, 1 H), 3.37 (s, 3 H, OCH_3), 3.38 (s, 3 H, OCH_3), 3.55 (m, 4 H, CH_3OCH_2), 3.80 (m, 4 H, CH_2CH_2OPh), 5.15–5.40 (m, 5 H, CH_2OPh, $COOCH$), 6.00 (m, 1 H, $PhCH{=}CH$), 6.35 (dd, 1 H, J = 15.5, 1.4 Hz, $PhCH{=}CH$), 6.75 (d, 1 H, J = 2.1 Hz, Ar H), 6.87 (d, 1 H, J = 2.1 Hz, Ar H); ^{13}C NMR ($CDCl_3$) δ 20.13, 21.37, 21.72, 31.23, 35.23, 37.65, 44.06, 59.01 (OCH_3), 67.70 (CH_3OCH_2), 67.81 (CH_3OCH_2), 71.15, 71.45, 71.51, 93.33 (OCH_2OPh), 93.63 (OCH_2OPh), 102.67, 105.64, 118.18, 128.57, 133.64, 136.78, 154.78, 158.75, 167.32 (PhC=O), 211.32 ($(CH_2)_2C$=O); HRMS calcd for $C_{29}H_{38}O_9$ 494.2505, found 494.2518 (M^+).

Compound 37 (Syringe Pump Method). To a three-necked flask equipped with a reflux condenser and two serum septa was added 10 mL of toluene, 0.0019 g (0.0016 mmol, 3.2 mol %) of $Pd(PPh_3)_4$, and 1 mL of a solution of 0.046 g (0.050 mmol) of (*S*)-(*E*)-11-(tributylstannyl)-6-oxo-10-undecen-2-yl 4,6-bis[[(2-methoxyethoxy)methyl]oxy]-2-iodobenzoate (**36**) in 5 mL of toluene. The solution was heated to reflux and the remainder of the substrate solution was added to the mixture over a 5-h period with a syringe pump. At this time, 0.0024 g (0.0021 mmol, 4.2 mol %) of additional $Pd(PPh_3)_4$ was added to the solution and the reaction was stirred for 3 h longer. The reaction mixture was cooled to 25 °C and concentrated in vacuo. The brown residue was purified by PTLC (two 10 × 20 cm plates, eluted with 30% EtOAc in hexanes and 40% EtOAc in hexanes) to yield 0.0097 g (39%) of a clear oil. The product was identical in all respects with **37** prepared by the high dilution method.

Compound 37 (Polymer-Supported Catalyst Method). A solution of 0.038 g (0.041 mmol) of (*S*)-(*E*)-11-(tributylstannyl)-6-oxo-10-undecen-2-yl 4,6-bis[[(2-methoxyethoxy)methyl]oxy]-2-iodobenzoate (**36**) and 0.013 g (0.0013 mmol, 3.2 mol %) of $Pd(PPh_3)_4$ on a polystyrene support (0.1 mmol of Pd/g polystyrene, 20% cross-link) in 5 mL of toluene was heated at reflux for 61 h. The solution was cooled to 25 °C and filtered to remove the catalyst. The solution was concentrated in vacuo to yield a yellow oil. The crude product was purified by PTLC (two 10 × 20 cm plates, eluted four times with 30% EtOAc in hexanes) to give 0.011 g (54%) of the desired product. The product was identical in all respects with **37** prepared by the high dilution method.

(*S*)-Zearalenone (1). A solution of 0.0027 g (0.0055 mmol) of (*S*)-2,4-bis[(2-methoxyethoxy)methyl]zearalenone (**37**) in 3 mL of a 2:1 mixture of THF and a 5% HCl solution was stirred at 25 °C for 9 days. At this time, 2 mL of a saturated $NaHCO_3$ solution was added to the mixture. The mixture was extracted with two 10-mL portions of ether, and the combined ether extracts were dried over anhydrous $MgSO_4$. The dried extracts were filtered, and the filtrate was concentrated in vacuo to yield a yellow oil. Purification by PTLC (one 10 × 20 cm plate, eluted once with 35% EtOAc in hexanes) yielded 0.0014 g (80%) of a white solid: R_f 0.46 in 50% EtOAc/hexanes; $[\alpha]^{24}_D$ −122° (c = 0.11 in MeOH) lit.[3] $[\alpha]^{24}_D$ −134° (c = 1.0 in MeOH); IR (neat) ν 3355 (b, OH), 2933, 1694, 1674, 1611, 1581, 1446, 1354, 1314, 1258 (C–O), 1199, 1170, 1120 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 1.38 (d, 3 H, J = 6.1 Hz, $COOCHCH_3$), 1.50 (m, 1 H), 1.63 (m, 4 H), 1.75 (m, 4 H), 2.17 (m, 4 H), 2.30–2.45 (m, 1 H), 2.61 (m, 1 H), 2.85 (ddd, 1 H, J = 2.6, 12.4, 15.5 Hz), 5.00 (m, 1 H, $COOCH$), 5.55 (bs, Ar OH), 5.68 (ddd, 1 H, J = 3.7, 10.4, 15.3 Hz, $PhCH{=}CH$), 6.35 (d, 1 H, J = 2.6 Hz, Ar H), 6.41 (d, 1 H, J = 2.6 Hz, Ar H), 7.00 (dd, J = 1.8, 15.1 Hz, $PhCH{=}CH$), 12.07 (s, 1 H, Ar OH); ^{13}C NMR ($CDCl_3$) δ 20.84, 20.99, 22.29, 31.00, 34.71, 36.66, 42.94, 73.46 (PhCOOCH), 102.42, 103.94, 108.35, 132.54, 133.13, 144.03, 160.37, 165.46, 171.30 (PhC=O), 211.46 ($(CH_2)_2C$=O); HRMS calcd for $C_{18}H_{22}O_5$ 318.1461, found 318.1470 (M^+). The ^{1}H NMR and ^{13}C NMR spectra were identical with those of an authentic sample purchased from the Aldrich Chemical Co.

Acknowledgment. We would like to thank the National Institutes of Health (NIH grant GM35694) for their generous financial support.

Registry No. 1, 17924-92-4; **3b**, 132260-45-8; **3c**, 132260-44-7; **3d**, 132260-43-6; **4a**, 132260-39-0; **4a** cyclic dimer, 132260-46-9; **4b**, 132260-40-3; **4c**, 132260-41-4; **4d**, 132260-42-5; **5a**, 64584-92-5; **5b**, 132260-52-7; **6**, 88-67-5; **6** methyl ester, 610-97-9; **8a**, 122593-90-2; **8b**, 132260-37-8; **8c**, 132260-38-9; **8d**, 132260-36-7; **9a**, 928-90-5; **9d**, 2774-84-7; **10a**, 4224-70-8; **10b**, 17696-11-6; **11a**, 4286-55-9; **11b**, 50816-19-8; **12a**, 129368-70-3; **12b**, 96045-13-5; **13a**, 73448-13-2; **13b**, 119837-87-5; **13c**, 96045-10-2; **13d**, 132260-32-3; **14a**, 132260-33-4; **14b**, 132260-34-5; **14c**, 132260-35-6; **14d**, 129056-86-6; **15a**, 132260-50-5; **15b**, 132260-51-6; **16**, 94563-21-0; **17**, 125180-18-9; **18**, 132260-47-0; **19**, 132260-48-1; **19** (de-iodo derivative), 132260-49-2; **22**, 132260-58-3; **23**, 132260-59-4; **24**, 2150-47-2; **25**, 132297-26-8; **26**, 132260-53-8; **27**, 132260-54-9; **28**, 132260-55-0; **29**, 132260-56-1; **30**, 132260-57-2; **31**, 15448-47-2; **32**, 64584-92-5; **32** TBDMS ether, 116773-95-6; **33**, 104784-04-5; **34**, 132260-60-7; **34** ketone, 132260-62-9; **35**, 132260-61-8; **36**, 132260-63-0; **37**, 132297-27-9; lithium acetylide–ethylenediamine complex, 50475-76-8.

Supplementary Material Available: ^{1}H and ^{13}C NMR spectra for compounds **3b**, **14a–d**, **17–19**, **23**, and **37** (21 pages). Ordering information is given on any current masthead page.