Palladium(0)-catalysed Cross-coupling Reactions of α-Alkoxyalkenylstannanes and α-Alkoxyalkenylzincs

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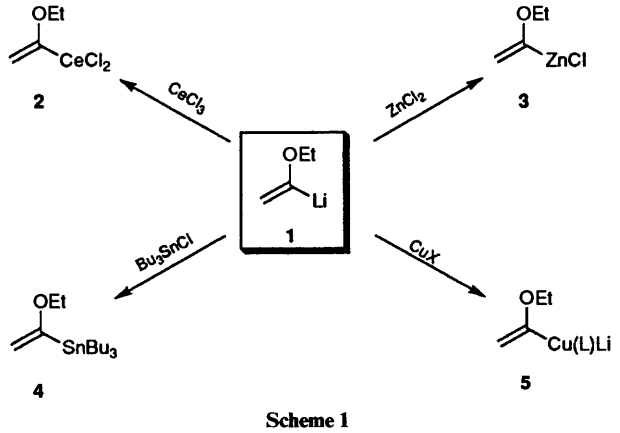
α-Alkoxyalkenylstannanes prepared by the Pd^0-catalysed hydrostannylation of 1-alkoxyalk-1-ynes, undergo Pd^0-catalysed Stille-type cross-coupling reactions with acid chlorides, aryl iodides and alkenyl trifluoromethanesulfonates. In the most complex case, an enol ether moiety was appended to a carbapenem nucleus. The coupling reaction was strongly dependent upon solvent, temperature, and added ligands. The method substantially extends the use of metallated enol ethers as nucleophilic acylation agents.

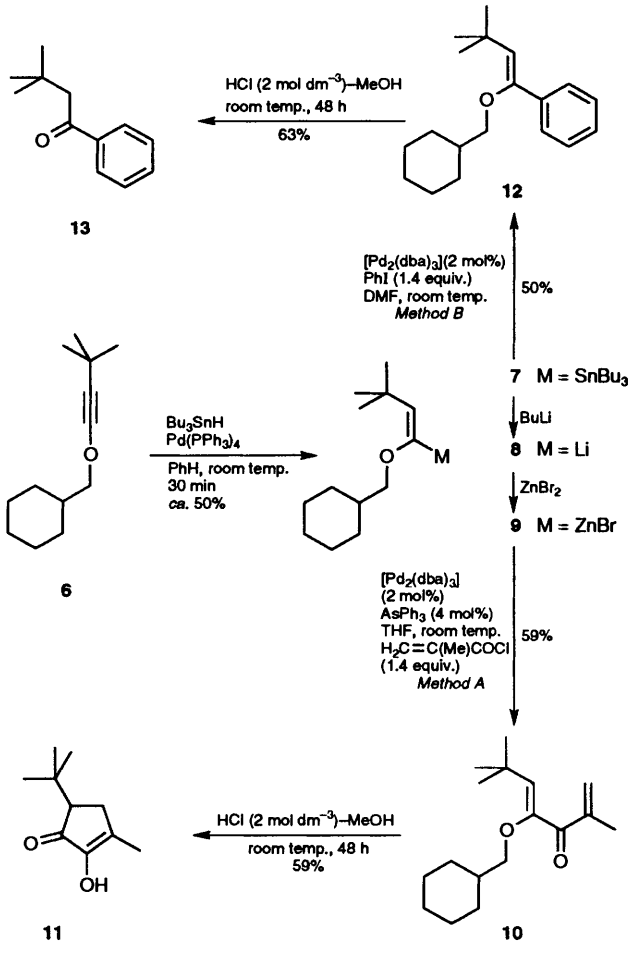
α-Ethoxyethenyllithium (**1**) and its methoxy analogue were first exploited as nucleophilic acetylating agents 20 years ago.[1,2] The lithium reagent **1** is highly nucleophilic but it is also highly basic; therefore, its reactions with carbon electrophiles have largely been limited to sterically unencumbered alkyl halides and carbonyl compounds.[2–4] The high basicity of **1** can be ameliorated by transmetallation to the cerium derivative **2** (to prevent enolisation on addition to hindered carbonyls)[5,6] or the zinc reagent **3** (to enable Pd-catalysed cross-coupling reactions with aryl and alkenyl halides and trifluoromethanesulfonates.[7–9] The tributylstannane **4** has also served as a mild substrate in Pd-catalysed coupling reactions[10–18] and the organocuprates **5** have been used in conjugate additions to enones (Scheme 1).[19,20]



Scheme 1

With such a rich and varied chemistry of α-alkoxyethenylmetal derivatives now extant, the dearth of reports regarding analogous reactions of longer chain homologues is conspicuous[21] and may be attributed to the failure of β-alkyl-substituted acyclic enol ethers to undergo clean lithiation under conditions generally applicable to ethoxyethene. Fortunately, α-alkoxyalkenylstannanes, which are now readily prepared by the Pd^0-catalysed hydrostannylation of 1-alkoxyalk-1-ynes (*e.g.* **6** ⟶ **7**),[22] easily transmetallate to the lithium derivatives on reaction with BuLi providing, for the first time, access to a much wider range of acyclic metallated enol ether derivatives. We now report that higher α-alkoxyalkenylstannanes[23] undergo Stille-type[24] sp^2–sp^2 cross-coupling reactions with arene, alkene and acyl electrophiles under mild conditions.[24]

In a brief survey of the reagents and conditions best suited for the Pd^0-catalysed coupling of α-alkoxyalkenylmetal derivatives, we began with the mildest protocol which had previously accomplished the efficient coupling of analogous α-phenylthioalkenylzinc reagents with a wide variety of electrophiles:[25] $[Pd_2(dba)_3]$ (dba = dibenzylideneacetone) (2 mol%) and $AsPh_3$ (4 mol%) in tetrahydrofuran (THF) at room temp. (method A).[26] The results were disappointing. Although α-alkoxyalkenylzinc reagent **9**, prepared in two simple steps from the stannane **7** (via **8**) (Scheme 2), underwent clean coupling

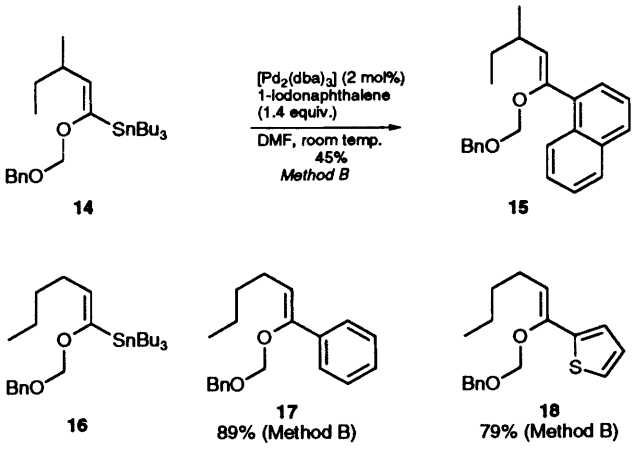


Scheme 2

with methacryloyl chloride to give the α-alkoxyenone **10** in 59% overall yield from **7**, the related coupling with iodobenzene was messy and purification complicated by contamination of the resultant enol ether **12** with inseparable byproducts derived

from the arsine. A far cleaner product was obtained in the direct coupling of stannane **7** with iodobenzene using $[Pd_2(dba)_3]$ in dimethylformamide (DMF) (method B)[27] giving enol ether **12** but only in 50% yield. As a further proof of structure, hydrolysis of the enol ether **12** in the usual way afforded the known acyl arene **13** in 63% yield. Attempted hydrolysis of enol ether **10** was accompanied by a Nazarov cyclisation leading to cyclopentenone derivative **11** (59%).

In order to establish whether the modest yields in the couplings outlined in Scheme 2 were a consequence of the size of the substituents, we examined some coupling reactions of α-alkoxylalkenylstannanes **14** and **16** using method B (Scheme 3).



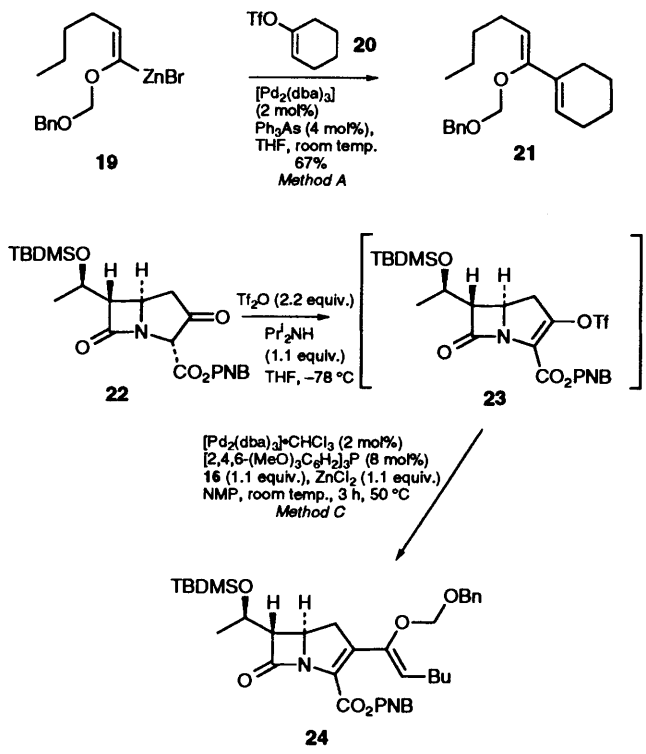
Scheme 3

The reduced steric demand of the Bu^s and benzyloxymethyl groups offered no improvement. Coupling with 1-iodonaphthalene gave a meagre 45% yield of enol ether **15**. On the other hand, stannane **16** coupled cleanly and efficiently with iodobenzene and 2-iodothiophene to produce enol ethers **17** and **18** in 89 and 79% yield respectively.

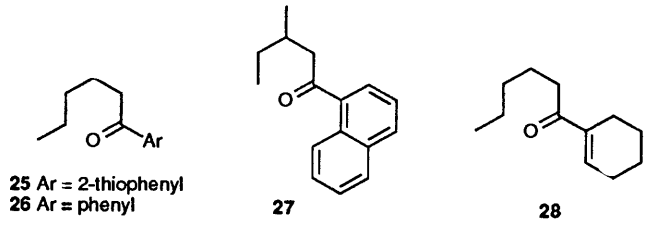
Application of method B to the coupling of stannane **16** and cyclohex-1-enyl trifluoromethanesulfonate **20** gave 30–40% of impure dienol ether **21**. Both the yield (53%) and quality of product improved by supplementing method B with 8 equiv. of LiCl. However, the best results (67% yield) were obtained using the organozinc reagent **19** in method A (Scheme 4). Neither method A nor method B could be applied to the coupling of the stannane **16** (or its zinc derivative **19**) to the carbapenem trifluoromethanesulfonate **23** (Scheme 4);[28] instead a third protocol (method C) was required whose success depended on the presence of the ligand tris(2,4,6-trimethoxyphenyl)-phosphine in conjunction with $[Pd_2(dba)_3]\cdot CHCl_3$ in *N*-methyl-2-pyrrolidone (NMP) as solvent.[29] The coupled carbapenem **24** was obtained in 50% yield.

Hydrolysis of the alkoxyalkene coupling products **15**, **17**, **18** and **21** gave the ketones **27**, **26**, **25** and **28** respectively.

In conclusion, by combining two Pd^0-catalysed reactions (hydrostannylation of 1-alkoxyalk-1-ynes and Stille coupling), we have extended the range of nucleophilic acylations now possible. However, it is clear from the discussion above that even within the narrow compass of electrophiles examined, no one set of conditions was generally applicable to the Stille coupling of α-metallated enol ethers. Furthermore, there were a number of electrophiles which gave messy reactions or failed altogether to couple with stannane **16** (or its corresponding organozinc derivative) under any of the methods described herein—electrophiles such as isobutyl chloroformate, isobutyryl chloride, 1-methyl-2-iodoindole, 4-iodopyrazole, 1-iodohept-1-yne or norbornenol trifluoromethanesulfonate. Coupling, if it occurred at all, was usually best accomplished in



Scheme 4 TBDMS = Bu^{t}Me$_2$Si, Tf = CF_3SO_2, PNB = *p*-$NO_2C_6H_4CH_2$



a dipolar, aprotic solvent (DMF or *N*-methyl-2-pyrrolidone) at room temp. All attempts to force coupling at elevated temperature failed. By contrast, α-phenylthioalkenylzinc reagents, which tolerate elevated temperatures, couple with a wider range of electrophiles in rather better yield.[25] Nevertheless, we have shown that higher α-alkoxyalkenyl metal derivatives undergo Pd^0-catalysed coupling reactions with typical representatives of the usual electrophilic substrates and the reaction is amenable to ligand tuning. Further improvements hinge upon the discovery of more active catalyst systems.

Experimental

Unless otherwise specified all yields quoted refer to compounds purified by column chromatography on silica gel with the eluent specified in parenthesis. Reactions requiring anhydrous conditions were conducted in a flame-dried apparatus under a static atmosphere of dry argon or nitrogen. Organic extracts were dried over $MgSO_4$ unless otherwise specified and evaporated at aspirator pressure on a rotary evaporator. Distillations in which the bath temperature is recorded were performed with a Kugelrohr apparatus. Lithium reagents were titrated in THF under argon against 1,3-diphenylacetone-*p*-tolylsulfonylhydrazone.[30] Zinc bromide was dried by heating at 60 °C/0.3 mmHg over P_2O_5 for 12 h. Commercial (Aldrich) $ZnCl_2$ in Et_2O (1 mol dm^{-3}) was used as supplied. Tris(dibenzylideneacetone)dipalladium and its chloroform complex were freshly prepared according to literature procedures.[31] Tris(2,4,6-

trimethoxyphenyl)phosphine was prepared according to the procedure of Ukai.[32]

^{1}H NMR spectra of all isolated compounds were recorded at 270 MHz in $CDCl_3$ which was stored over Mg unless otherwise specified. ^{1}H Chemical shifts are reported in ppm relative to $CHCl_3$ (δ 7.27). *J* Values are given in Hz. ^{13}C NMR spectra are quoted relative to $CDCl_3$ (δ 77.1) as an internal standard in which C–H coupling was analysed using the distortionless enhancement by phase transfer (DEPT) spectral editing technique with second pulses at 90 and 135°. C–H Coupling is indicated by an integer 0–3 in parenthesis following the ^{13}C chemical shift value denoting the number of coupled protons. Peak intensities in the IR spectra are defined as strong (s), medium (m) or weak (w). Accurate mass determinations and low resolution mass spectra were made on distilled compounds estimated to be at least 95% pure by NMR spectroscopy and thin layer chromatography.

(Z)-4-(*Cyclohexylmethoxy*)-2,6,6-*trimethylhepta*-1,4-*dien*-3-*one* **10**. *Method A, Typical Procedure*.—To a solution of (*E*)-1-(cyclohexylmethoxy)-3,3-dimethyl-1-(tributylstannyl)-but-1-ene **7** (1.00 g, 2.06 mmol) in THF (10 cm^3) at −78 °C, was added butyllithium (1.53 mol dm^{-3}; 1.48 cm^3, 2.27 mmol) dropwise. After 15 min at −78 °C, $ZnBr_2$ (0.07 mol dm^{-3} in THF, 3.1 cm^3, 2.3 mmol) was added and the reaction stirred at ambient temperature for 1 h. A solution of methacryloyl chloride (0.28 cm^3, 2.88 mmol), $AsPh_3$ (4 mol%, 25.2 mg) and [$Pd_2(dba)_3$] (2 mol%, 38.0 mg) in THF (10 cm^3) was stirred in a separate flask for 10 min and then added to the organozinc intermediate **9**. After 10 min, the solvent was evaporated under reduced pressure. Purification of the residue by column chromatography (5% Et_2O in hexanes) and Kugelrohr distillation gave **10** (320 mg, 1.21 mmol, 59%) as a colourless oil; b.p. 150 °C (bath)/0.2 mmHg; ν_{max}(film)/cm^{-1} 1655s, 1625m 1062s and 734s; δ_H(270 MHz; $CDCl_3$) 5.79 and 5.71 (1 H each, m), 5.53 (1 H, s), 3.42 (2 H, d), 1.93 (3 H, s), 1.64–1.83 (6 H, m), 0.85–1.04 (3 H, m) and 1.17 (9 H, s); δ_C(67.5 MHz; $CDCl_3$) 195.4 (0), 151.8 (0), 144.2 (0), 134.7 (1), 125.6 (2), 75.6 (2), 38.4 (1), 32.4 (0), 30.1 (3, 3 C) 29.9 (2, 2 C), 26.6 (2), 25.8 (2, 2 C) and 18.2 (3) (Found: *m/z* 265.2168. $C_{17}H_{28}O_2$ + H requires *M*, 265.2154).

(Z)-1-(*Benzyloxymethoxy*)-1-(*cyclohex*-1-*enyl*)*hex*-1-*ene* **21**. —*Coupling of stannane* **16** (1.00 mmol) with cyclohex-1-enyl trifluoromethanesulfonate **20** according to method A gave the *title compound* (200 mg, 0.666 mmol, 67%) as a colourless oil, b.p. 160 °C (bath)/0.1 mmHg; ν_{max}(film)/cm^{-1} 1667w, 1628w, 1048s, 1013s, 734s and 686s; δ_H(270 MHz; $CDCl_3$) 7.30–7.38 (5 H, m), 5.04 (1 H, t, *J* 7.2), 4.93 (1 H, t, *J* 1.7), 4.80 (2 H, s), 4.65 (2 H, s), 2.23–2.25 (2 H, m), 2.12–2.13 (4 H, m), 1.60–1.66 (4 H, m), 1.34–1.39 (4 H, m) and 0.90 (3 H, t, *J* 7.1); δ_C(67.5 MHz; $CDCl_3$) 153.6 (0), 137.9 (0), 132.1 (0), 128.4 (1, 2 C), 127.9 (1, 2 C), 127.7 (1), 124.5 (1), 113.9 (1), 95.2 (2), 71.1 (2), 32.2 (2), 25.7 (2), 25.7 (2), 25.5 (2), 22.8 (2), 22.6 (2) and 14.1 (3); *m/z* (EI mode) 300 (M$^{\bullet+}$, 18%), 270 (16), 262 (31), 213 (26), 190 (52), 172 (24), 161 (16), 135 (16), 109 (26) and 91 (100) (Found: *m/z* 300.2091. $C_{20}H_{28}O_2$ requires *M*, 300.2089).

(Z)-1-(*Cyclohexylmethoxy*)-3,3-*dimethyl*-1-*phenylbut*-1-*ene* **12**. *Method B, Typical Procedure*.—A mixture of [$Pd_2(dba)_3$] (2 mol%, 38 mg) and iodobenzene (0.31 cm^3 1.4 mmol) in DMF (10 cm^3) was stirred under argon at ambient temperature for 10 min and then added to a solution of stannane **7** (970 mg, 2.0 mmol) in DMF (15 cm^3). TLC showed complete consumption of **7** after 6 h stirring at ambient temperature. 10% NH_4OH (20 cm^3) was added and the reaction stirred for several minutes. The product was extracted into diethyl ether (20 cm^3) and the extract washed with brine (3 × 10 cm^3), dried, and concentrated under reduced pressure. Purification of the residue by column chromatography (2% Et_2O in hexanes) followed by Kugelrohr distillation provided **12** (270 mg, 0.993 mmol, 50%) as a colourless oil; b.p. 140 °C (bath)/0.07 mmHg; ν_{max}(film)/cm^{-1} 1645m, 1330s, 1266s, 1070s, 774s, 754s, 737s and 699s; δ_H(270 MHz; $CDCl_3$) 7.28–7.48 (5 H, m), 5.10 (1 H, s), 3.36 (2 H, d), 1.76–1.90 (6 H, m), 1.26 (9 H, s) and 1.02–1.35 (5 H, m); δ_C(67.5 MHz; $CDCl_3$) 153.6 (0), 138.0 (0), 128.9 (1), 128.3 (1), 127.6 (1), 127.3 (1), 126.8 (1), 124.6 (1), 75.5 (2), 38.7 (1), 32.3 (0), 31.0 (3, 3 C), 30.3 (2, 2 C), 26.8 (2) and 26.1 (2, 2 C); *m/z* (EI mode) 272 (M$^{\bullet+}$, 8%), 267 (100), 249 (5), 194 (8), 177 (7), 108 (17), 106 (15), 91 (18) and 35 (14) (Found: *m/z* 272.2134. $C_{19}H_{28}O$ requires *M*, 272.2140).

(Z)-1-*Benzyloxymethoxy*-3-*methyl*-1-(1-*naphthyl*)*pent*-1-*ene* **15**.—Coupling of stannane **14** (1.00 mmol) with 1-iodonaphthalene (1.4 mmol) according to method B gave the *title compound* (160 mg, 0.462 mmol, 46%) as a colourless oil, b.p. 245 °C (bath)/1.0 mmHg; ν_{max}(film)/cm^{-1} 1668s, 1454s, 1380s, 1195s, 1114s, 1083s, 1024s, 909s, 804s, 773s, 733s and 607s; δ_H(270 MHz; $CDCl_3$) 8.23 (1 H, dd, *J* 8.3, 2.7), 7.85 (2 H, dd, *J* 8.8, 7.04), 7.55 (1 H, dd, *J* 7.0, 1.3), 7.50 (1 H, dd, *J* 7.7, 6.0), 7.46 (1 H, d, *J* 8.1), 7.43 (1 H, d, *J* 7.0), 7.28–7.41 (5 H, m, Ph), 4.88 (1 H, d, *J* 9.7), 4.71 (2 H, AB system, *J* 27), 4.70 (2 H, AB system, *J* 11.6), 2.90–3.10 (1 H, m), 1.35–1.55 (2 H, m), 1.15 (3 H, d, *J* 6.8) and 1.05 (3 H, t, *J* 7.3); δ_C(67.5 MHz, $CDCl_3$) 150.3 (0), 137.8 (0), 134.2 (0), 133.6 (0), 132.2 (0), 128.9 (1), 128.5 (1, 2 C), 128.4 (1), 127.9 (1, 2 C), 127.8 (1), 127.0 (1), 126.4 (1), 126.0 (1), 125.5 (1), 123.5 (1), 123.4 (1), 91.9 (2), 70.3 (2), 32.2 (1), 30.7 (2), 21.3 (3) and 12.4 (3); *m/z* (EI mode) 346 (M$^{\bullet+}$, 57%), 316 (11), 287 (10), 245 (12), 218 (22), 155 (47), 127 (27), 91 (100) and 69 (1) (Found: *m/z* 346.1936. $C_{19}H_{28}O$ requires *M*, 346.1933).

(Z)-1-(*Benzyloxymethoxy*)-1-*phenylhex*-1-*ene* **17**.—Coupling of stannane **16** (1.00 mmol) with iodobenzene (1.4 mmol) according to method B gave the *title compound* (231 mg, 0.887 mmol, 89%) as a colourless oil; b.p. 195 °C (bath)/0.4 mmHg; ν_{max}(film)/cm^{-1} 1657m, 1167s, 1105s, 1038s, 1014s, 771s, 735s and 697s; δ_H(270 MHz; $CDCl_3$) 7.47–7.50 (2 H, d, *J* 4.4), 7.28–7.38 (8 H, m), 5.37 (1 H, t, *J* 7.3), 4.97 (2 H, s), 4.79 (2 H, s), 2.38 (2 H, dt, *J* 7.3, 7.2), 1.40–1.48 (4 H, m) and 0.95 (3 H, t, *J* 7.1); δ_C(67.5 MHz; $CDCl_3$) 151.8 (0), 137.7 (0), 136.6 (0), 128.4 (1, 2 C), 128.4 (1, 2 C), 127.8 (1, 2 C), 127.8 (1, 2 C), 126.3 (1, 2 C), 116.6 (1), 93.8 (2), 70.9 (2), 32.0 (2), 25.8 (2), 22.7 (2) and 14.1 (3); *m/z* (EI mode) 296 (M$^{\bullet+}$, 8%), 267 (100), 249 (5), 194 (8), 177 (7), 108 (17), 106 (15), 91 (18) and 35 (14) (Found: *m/z* 296.1776. $C_{20}H_{24}O_2$ requires *M*, 296.1773).

(Z)-1-(*Benzyloxymethoxy*)-1-(*thiophen*-2-*yl*)-*hex*-1-*ene* **18**.—Coupling of stannane **16** (2.00 mmol) with 2-iodothiophene (2.8 mmol) according to method B gave the *title compound* (480 mg, 1.59 mmol, 79%) as a colourless oil, b.p. 230 °C (bath)/0.1 mmHg; ν_{max}(film)/cm^{-1} 3066w, 3030w, 2956s, 2857m, 1454m, 1249m, 1165m, 1105m, 1045s, 1006s, 910m, 734s and 697s; δ_H(270 MHz; $CDCl_3$) 7.32–7.38 (5 H, m), 7.20 (1 H, dd, *J* 1.2, 5.0), 7.11 (1 H, dd, *J* 5.0, 3.7), 6.99 (1 H, dd, *J* 5.0, 3.7), 5.45 (1 H, t, *J* 7.4), 5.08 (2 H, s), 4.84 (2 H, s), 2.30–2.38 (2 H, dt, *J* 7.3, 7.3), 1.33–1.59 (4 H, m) and 0.94 (3 H, distorted t, *J* 7.0); δ_C(67.5 MHz; $CDCl_3$) 146.7 (0), 140.7 (0), 137.6 (0), 128.5 (1, 2 C), 127.9 (1, 2 C), 127.3 (1), 124.6 (1, 2 C), 124.1 (1), 116.6 (1), 94.8 (2), 71.2 (2), 31.9 (2), 25.8 (2), 22.7 (2) and 14.1 (3); *m/z* (EI mode) 302 (M$^{\bullet+}$, 7%), 272 (11), 215 (15), 174 (19), 111 (35) and 91 (100) (Found: *m/z* 302.1324. $C_{18}H_{22}O_2S$ requires *M*, 302,1341).

p-*Nitrobenzyl* (2R,5R,6R)-3-[1-(*Benzyloxymethoxy*)*hex*-1-*enyl*]-6-[(1R)-1-(tert-*butyldimethylsiloxy*)*ethyl*]-7-*oxo*-1-*azabicyclo*[3.2.0]*hept*-2-*ene*-2-*carboxylate* **24**. *Method C*.—To a stirred solution of ketone **22** (1.48 mmol, 684 mg) (prepared in 54% overall yield using the procedure of Mori *et al.*[33] and Ueda

et al.[34]) at −78 °C under Ar, was added diisopropylamine (1.625 mmol, 0.23 cm^3). After 10 min trifluoromethanesulfonic anhydride (Tf_2O) (1.62 mmol, 0.27 cm^3) was added to the yellow solution. TLC showed incomplete conversion to the trifluoromethanesulfonate after 30 min. Another 1.1 equiv. of Tf_2O was added and the reaction stirred for an additional 15 min then *N*-methyl-2-pyrrolidone (7.2 cm^3) was added, followed by $[Pd_2(dba)_3]\cdot CHCl_3$ (2 mol%, 30.1 mg), tris(2,4,6-trimethoxyphenyl)phosphine (8 mol%, 65 mg) and (*E*)-1-(benzyloxymethoxy)-1-(tributylstannyl)hex-1-ene **16** (1.6 mmol, 790 mg). Finally, a solution of $ZnCl_2$ in Et_2O (1.63 mmol, 1.63 cm^3 of a 1 mol dm^{-3} solution) was added. The cooling bath was removed and the reaction temperature was rapidly raised to ambient temperature using a lukewarm water bath. An intense red colour developed on warming. After stirring for 3 h at ambient temperature, the reaction was diluted with Et_2O, washed with water (3 × 10 cm^3), and brine (3 × 10 cm^3), dried over $MgSO_4$, filtered and concentrated under reduced pressure. Purification of the residue by column chromatography (2% Et_2O in hexanes) provided the *title compound* **24** (479 mg, 7.40 mmol, 50%) as a labile colourless oil; ν_{max}(film)/cm^{-1} 1781s, 1730s, 1608m, 1523s and 735s; δ_H(270 MHz; $CDCl_3$) 8.17 (2 H, d, *J* 8.9), 7.58 (2 H, d, *J* 9.0), 7.28–7.40 (5 H, m), 5.37 (1 H, d, *J* 13.9, $CH_aC_6H_4$), 5.23 (1 H, d, *J* 13.7, $CH_bC_6H_4$), 5.19 (1 H, t, *J* 7.3, $CH{=}COCH_2$), 4.87 (2 H, s, OCH_2O), 4.67 (2 H, s, $PhCH_2O$), 4.14–4.28 (2 H, m, $NCHCH_2$, $CHCH_3$), 3.10 (1 H, dd, *J* 5.4, 3.1, $O{=}CCHCHCH_3$), 3.00 (2 H, d, *J* 9.5, $CHCH_2$), 2.20–2.35 (2 H, m, $C{=}CCH_2$), 1.18–1.45 (4 H, m, $CH_2CH_2CH_3$), 1.22 (3 H, d, *J* 6.2, CH_3CH), 0.88 (3 H, t, *J* 6.8, CH_2CH_3), 0.87 (9 H, s, CMe_3) and 0.08 and 0.07 (3 H each, s, $SiMe_2$); δ_C(67.5 MHz; $CDCl_3$) 176.6 (0, O=C–N), 160.6 (0, CO_2PNB), 147.5 (0, $C_6H_4NO_2$), 145.0 (0, N–C=C), 142.9 (0, CH_2C_{Ar}), 138.6 (0, O*C*=C), 137.3 (0, C_6H_5), 128.5 (1, 2 C, C_6H_5), 128.2 (1, 2 C, C_6H_4), 128.1 (1, 1 C, C_6H_5), 127.9 (1, 2 C, C_6H_5), 127.7 (1, 2 C, C_6H_4), 123.8, 123.6 (1, 2 C, C_6H_4), 94.4 (2, OCH_2O), 70.8 (2, $PhCH_2$), 67.3 (1, *C*HCO), 65.7 (1, *C*HCH_2), 65.4 (2, *C*$H_2C_6H_4$), 52.2 (*C*HOTBS), 40.1 (2, *C*H_2CCO), 31.5 (2, $OC{=}CCH_2$), 25.7 (3, 3 C, CMe_3), 25.4 (2, *C*$H_2CH_2CH_3$), 22.5 (3, *C*$H_3CHOTBS$), 22.4 (2, *C*H_2CH_3), 18.0 (0, *C*Me_3) and −4.25 (3, 2 C, $SiMe_2$); *m*/*z* (EI mode) 664 ($M^{\bullet+}$, 2%), 498 (14), 340 (14), 298 (27), 159 (37), 115 (19), 91 (100) and 73 (47) (Found: *m*/*z* 664.3165. $C_{36}H_{48}O_8Si$ requires *M*, 664.3180).

Hydrolysis of the Alkoxyalkene Coupling Products. Typical Procedure.—A mixture of HCl (2 mol dm^{-3}; 7 cm^3), MeOH (7 cm^3) and enol ether (1 mmol) was stirred for two days at room temp. The reaction mixture was poured onto aq. $NaHCO_3$ (10%, 15 cm^3) and further aq. $NaHCO_3$ was added until effervescence ceased. The crude product was extracted into diethyl ether (3 × 15 cm^3) and dried over $MgSO_4$. Purification by column chromatography (10% EtOAc in hexanes) followed by Kugelrohr distillation gave the following ketones: 5-*tert*-*butyl*-2-*hydroxy*-3-*methylcyclopent*-2-*en*-1-*one* **11** (59%), m.p. 114–118 °C (EtOH); ν_{max}(film)/cm^{-1} 3291m, 1710s, 1663s, 1470s, 1422s, 1402s, 1368s, 1261s, 1209s, 1105s, 896s and 758s; δ_H(270 MHz; $CDCl_3$) 5.92 (1 H, br, OH), 2.41 (1 H, ddq, CH_a, *J* 17.9, 6.4, 1.3), 2.25–2.27 (1 H, m), 2.23 (1 H, ddq, CH_b, *J* 17.9, 2.7), 2.00 (3 H, s) and 0.98 (9 H, s); δ_C(67.5 MHz; $CDCl_3$) 204.4 (0), 149.1 (0), 142.1 (0), 52.6 (1), 33.6 (0), 31.6 (2), 28.2 (3, 3 C) and 14.3 (3); *m*/*z* (EI mode) 168 ($M^{\bullet+}$, 5%), 153 (17), 125 (15), 112 (97), 107 (10), 94 (100), 91 (10), 66 (32), 57 (61), 53 (13), 41 (65) and 29 (32). 3,3-*Dimethyl*-1-*phenylbutan*-1-*one* **13**[35] (63%); ν_{max}(film)/cm^{-1} 1675s; δ_H(270 MHz; $CDCl_3$) 7.95 and 7.52 (1 H each, d, *J* 7.0), 7.42–7.47 (3 H, m, Ph), 2.87 (2 H, s) and 1.07 (9 H, s); δ_C(67.5 MHz; $CDCl_3$) 200.6 (0), 138.7 (0), 132.8 (1), 128.6 (1, 2 C), 128.3 (1, 2 C), 50.2 (2), 31.5 (0) and 30.2 (3, 3 C); *m*/*z* (EI mode) 176 ($M^{\bullet+}$, 12%), 120 (81), 105 (100) and 77 (41). 1-(*thiophen*-2-*yl*)*hexan*-1-*one* **25** (83%); ν_{max}(film)/cm^{-1} 1664s; δ_H(270 MHz; $CDCl_3$) 7.69 (1 H, dd, *J* 1.2, 3.7), 7.6 (1 H, dd, *J* 3.7, 5.0), 7.11 (1 H, dd, *J* 3.8, 4.9), 2.87 (2 H, t, *J* 7.5), 1.71–1.76 (2 H, m), 1.32–1.36 (4 H, m) and 0.89 (3 H, t, *J* 7.1); δ_C(67.5 MHz; $CDCl_3$) 193.7 (0), 144.6 (0), 133.4 (1), 131.8 (1), 128.1 (1), 39.5 (2), 31.6 (2), 24.6 (2), 22.6 (2) and 14.0 (3); *m*/*z* (EI mode) 182 ($M^{\bullet+}$, 5%), 139 (10), 126 (77), 111 (100), 83 (10) and 39 (27). 1-*Phenylhexan*-1-*one* **26**[36] (75%); ν_{max}(film)/cm^{-1} 1686s; δ_H(270 MHz; $CDCl_3$) 7.95 (2 H, dd, *J* 7.0, 1.7, 3-H, 5'H), 7.52 (1 H, tt, *J* 7.3, 2.4, 3'-H), 7.44 (1 H, dd, *J* 7.5, 1.3, 2'-H), 7.42 (1 H, dd, *J* 7.2, 1.7, 4'-H), 2.94 (2 H, t, *J* 7.5), 1.73 (2 H, tt, *J* 7.4), 1.35 (4 H, tq, *J* 7.4, 3.7) and 0.90 (3 H, t, *J* 7.0); δ_C(67.5 MHz; $CDCl_3$) 200.4 (0), 137.1 (0), 132.8 (1), 128.5 (1, 2 C), 128.0 (1, 2 C), 38.5 (2), 31.5 (0), 24.0 (2), 22.5 (2) and 13.9 (3); *m*/*z* (EI mode) 176 ($M^{\bullet+}$, 12%), 120 (73), 105 (100) and 77 (43). 3-*Methyl*-1-(1-*naphthyl*)*pentan*-1-*one* **27** (87%); ν_{max}(film)/cm^{-1} 1682s; δ_H(270 MHz; $CDCl_3$) 8.60 (1 H, dd, *J* 0.8, 8.6), 7.97 (1 H, d, *J* 8.3), 7.88 (1 H, dd, *J* 8.3, 0.7), 8.84 (1 H, dd, *J* 7.2, 1.1), 7.47–7.63 (3 H, m), 3.08 (1 H, dd, *J* 15.6, 5.7), 2.86 (1 H, dd, *J* 15.6, 8.1), 2.09–2.23 (1 H, m), 1.22–1.56 (2 H, m), 1.03 (3 H, d, *J* 6.8) and 0.959 (3 H, t, *J* 7.5); δ_C(67.5 MHz; $CDCl_2$) 205.2 (0), 136.9 (0, C-10'), 134.1 (0, C-1'), 132.3 (1, C-4'), 130.2 (0, C-9'), 128.5 (1, C-2'), 127.9 (1, C-7'), 127.3 (1, C-6'), 126.5 (1, C-5'), 125.9 (1, C-8'), 124.5 (1, C-3'), 49.5 (2), 31.9 (1), 29.8 (2), 19.7 (3) and 11.5 (3); *m*/*z* (EI mode) 226 ($M^{\bullet+}$, 27%), 170 (45), 155 (100) and 127 (56). 1-(*Cyclohex*-1-*enyl*)*hexan*-1-*one* **28**[37] (58%); ν_{max}(film)/cm^{-1} 1670s and 1638s; δ_H(270 MHz; $CDCl_3$) 6.88 (1 H, br s), 2.60 (2 H, t, *J* 7.5), 2.20–2.30 (4 H, m), 1.59–1.61 (7 H, m), 1.26–1.30 (5 H, m) and 0.88 (3 H, t, *J* 6.7); δ_C(67.5 MHz; $CDCl_3$) 202.0 (0), 139.6 (1), 139.4 (0), 37.2 (2), 31.8 (2), 26.2 (2), 24.8 (2), 23.3 (2), 22.7 (2), 22.2 (2), 21.8 (2) and 14.1 (3); *m*/*z* (EI mode) 180 ($M^{\bullet+}$, 3%), 124 (41), 109 (100), 81 (87), 53 (20) and 41 (27).

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