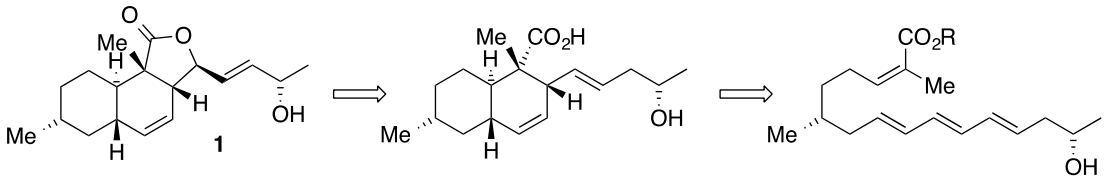
A Synthesis of Allahabadolactone A

Kongchen Wang and Roderick W. Bates*
Division of Chemistry and Biological Chemistry, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637371.

roderick@ntu.edu.sg

Abstract
A synthesis of Allahabadolactone A is described employing diastereoselective Diels-Alder and selenocyclisation reactions, starting from (*R*)-citronellal and propylene oxide. The Diels-Alder substrate is built up in an efficient manner by rhodium catalysed alkyne hydroboration and palladium catalysed coupling reactions of *E*-1,2-dichloroethene. It is observed that the Diels-Alder reaction only displays high diastereoselectivity when the diene bears an additional alkene substituent, but not an alkyne substituent.

Introduction
Allahabadolactone A **1** and its isomer allahabadolactone B were isolated from the fungus *Aspergillus allahabadii* and shown to have modest cytotoxic activity.[1] The structure was solved by crystallographic means and this natural product was shown to have a *trans*-decalin structure, with a double bond in one ring, appended to a substituted lactone. The mono-unsaturated decalin moiety with the same methyl substituent is also found in the natural products oblongolide,[2] equisetin,[3-6] fusarisetin,[6-9] paecilosetin,[10] phomasetin,[11] cryptocin[12] and aspermytin.[13] The lactone moiety distinguishes the allahabadolactones. The authors proposed a biosynthetic pathway involving an intramolecular Diels-Alder reaction[14] and a late stage lactone formation by means of a C-H bond oxidation.

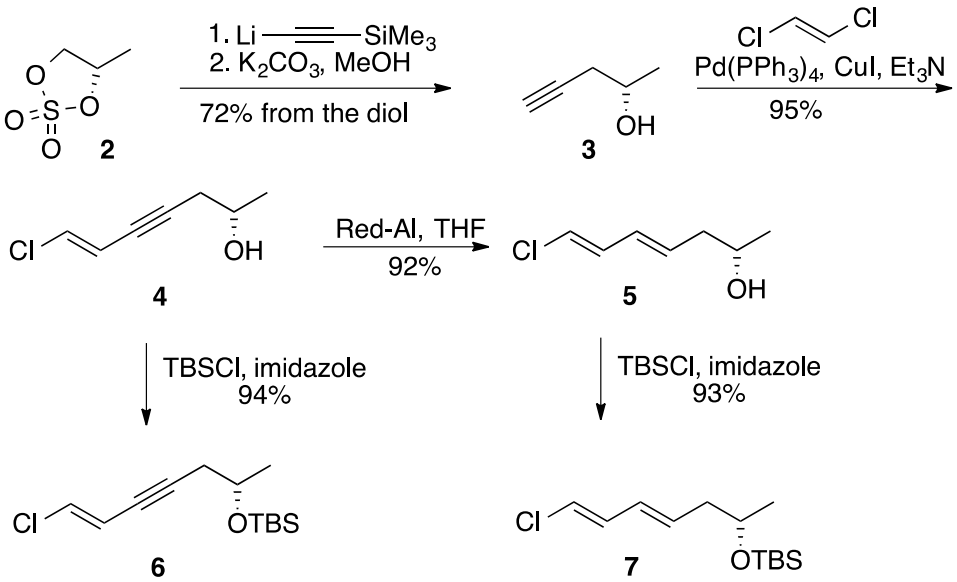


Scheme 1. Allahabadolactone retrosynthesis

We proposed to employ an intramolecular Diels-Alder (IMDA) reaction[2-9,15-17] for the construction of the decalin, and an electrophile-induced ring closure onto an alkene for lactone formation (Scheme 1).[18-20] This latter transformation would have the effect of moving the double bond by one place and, hence, allows the use of readily available propylene oxide or an equivalent as the source of the side chain stereogenic centre. Citronellal is a well precedented source of the stereogenic centre bearing the methyl group.

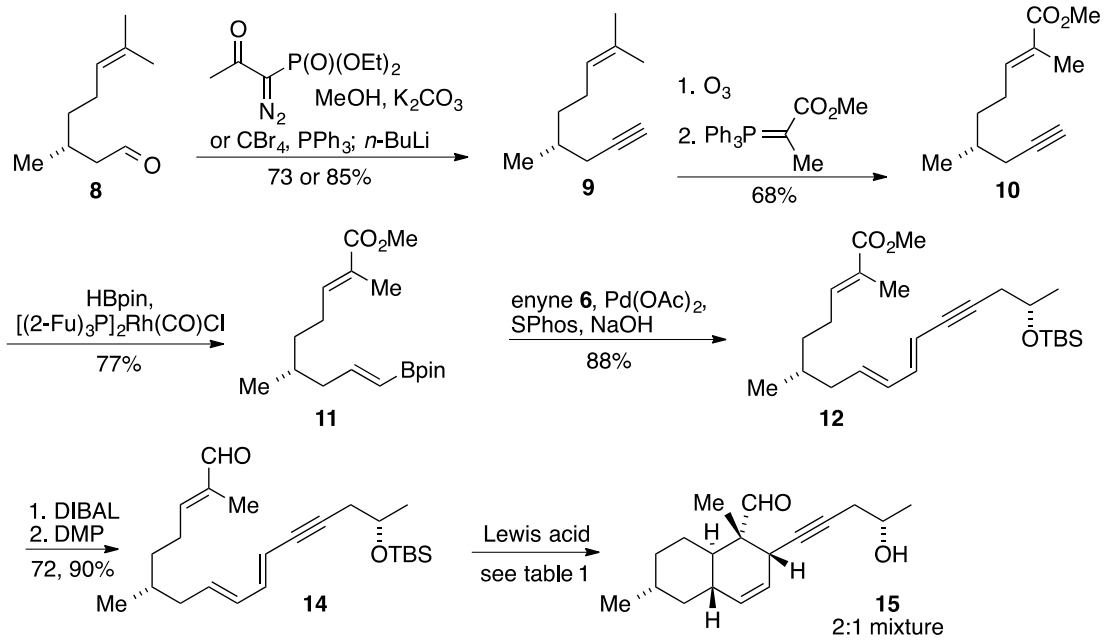
Results and Discussion
The cyclic sulfate **2** derived from (*S*)-propylene glycol was subjected to ring opening, followed by desilylation to give the alkynol **3** (Scheme 2).[21] Sonogashira coupling with an excess of *trans*-1,2-dichloroethene[22] proceeded smoothly to

give the enynol **4**. Reduction of enynol **4** to the corresponding *E*,*E*-dienol **5** using lithium aluminium hydride proved difficult and the reaction was plagued by hydrodechlorination. We eventually found that this transformation could be achieved with Red-Al to give the corresponding dienol **5** as, exclusively, the *E*, *E*-isomer. Both alcohols were converted into their TBS ethers, **6** and **7**, routinely.



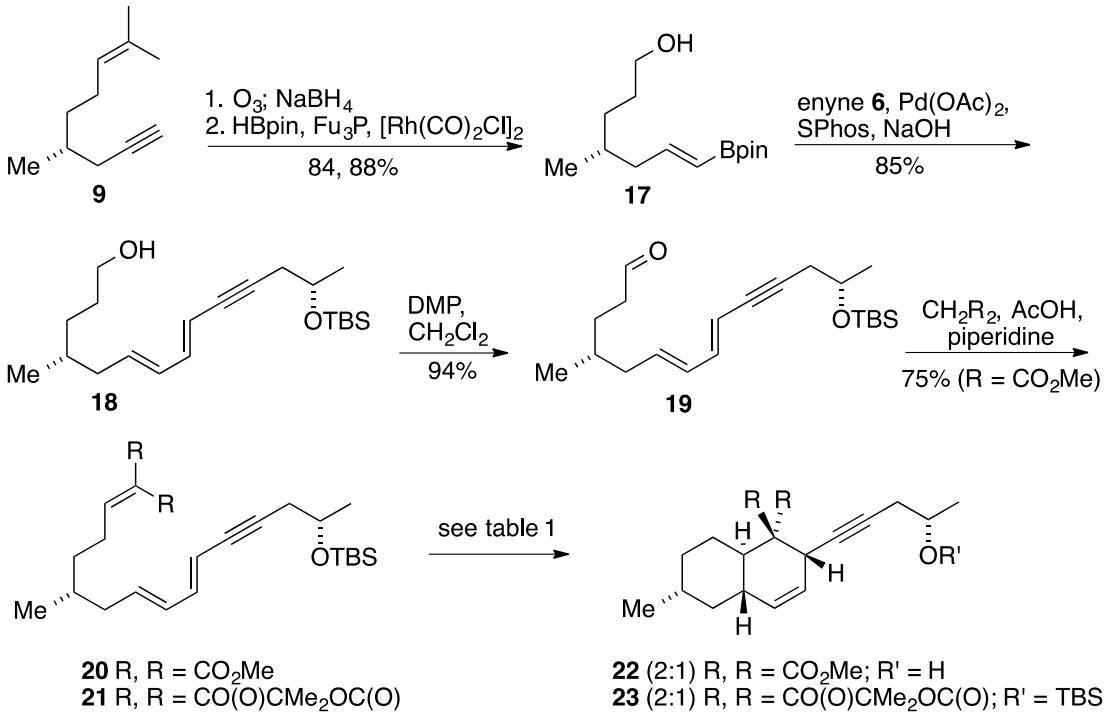
Scheme 2. Diene and enyne synthesis

Following the procedure in our previous report,[23] treatment of citronellal **8**[24] with the Ohira-Bestmann reagent[25] or the Corey-Fuchs reagent[26] gave the anticipated alkyne **9** (scheme 3). Operationally, the use of the Ohira-Bestmann reagent was more convenient, although slightly lower yielding. Ozonolysis,[27] followed by an *in situ* Wittig reaction yielded the unsaturated ester **10**. Hydroboration of ester **10** with pinacolatoborane in the presence of (2-Fu$_3$P)$_2$Rh(CO)Cl delivered vinyl boronate **11** cleanly. Suzuki coupling could then be effected using a catalytic system derived from palladium(II) acetate and Sphos in the presence of sodium hydroxide to give trienyne **12**.[28] No product was obtained when catalysts employing PPh_3 as a ligand were used. Gratifyingly, the ester was not hydrolysed under these conditions, provided that the reaction was not left longer than overnight. When weaker bases, potassium or cesium carbonate, were used, no product was obtained. Not unexpectedly, trienyne **12** failed to undergo the IMDA reaction upon treatment with a variety of Lewis acids, BF_3•OEt_2, $AlCl_3$[29,30] and Me_3Al, at up to 0 °C. The corresponding aldehyde **14**, however, did so on treatment with BF_3•OEt_2 at 0 °C. To our disappointment, the product **15** was isolated as an inseparable 2:1 mixture of diastereoisomers. The major isomer was presumed to be the *endo* isomer; the stereochemistry of the minor isomer was not determined.



Scheme 3. The first Diels-Alder approach

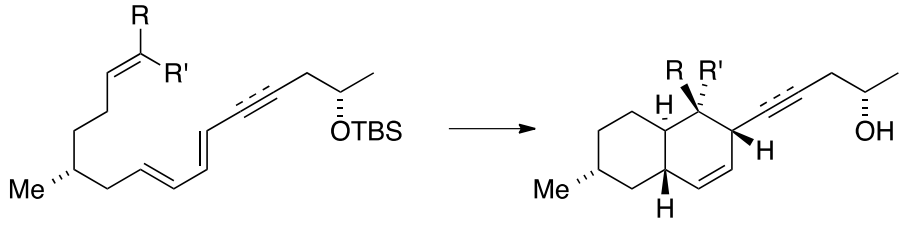
We anticipated that a system in which the dienophilic alkene carried two electron withdrawing groups would be more reactive, allowing the use of lower temperatures (scheme 4). To test this concept, alkyne **9** was subjected to ozonolysis followed by a reductive work up with sodium borohydride to give alcohol **17**. Rhodium catalysed hydroboration, Suzuki coupling and Dess-Martin reoxidation of the alcohol gave aldehyde **19**. The Knoevenagel reaction with dimethyl malonate gave an IMDA substrate **20** which underwent this reaction on treatment with $AlCl_3$ at -78° C, but gave a somewhat complex mixture that appeared to contain a 2:1 mixtures of diastereoisomers of cycloadduct **22**, with loss of the TBS group. On the other hand, when aldehyde **19** was subjected to a Knoevenagel reaction with Meldrum's acid, a tandem condensation-cycloaddition occurred and the Knoevenagel product **21** could neither be observed nor isolated. This is consistent with the known higher reactivity of Meldrum's acid Knoevenagel products.[31,32] The Diels-Alder product **23** was once again obtained as a 2:1 mixture of diastereoisomers, though, in this case the TBS group was retained.



Scheme 4. The Second Diels-Alder Approach

We suspected that the poor diastereoselectivity in this series of Diels-Alder reactions might be due to the alkynyl moiety. Thus, the dienol TBS ether **7** was subjected to Suzuki coupling with boronic ester **11** to give tetraene **24**, i.e. a dihydro version of trieneyne **12** (scheme 5). Conversion of the ester group by a reduction-oxidation sequence gave aldehyde **26**. To our delight, aldehyde **26** underwent a Lewis acid catalysed IMDA reaction to give the decalin as a single stereoisomer **27**, with concomitant loss of the silyl group. This reaction did not occur at -78° C, but proceeded slowly (overnight) at -40° C. At 0 °C, the reaction was rapid (1 hour) and gave the same selectivity. Amongst the Lewis acids, studied (entries 7-10), $AlCl_3$ gave the best results. This cycloaddition product was assigned the stereochemistry shown based upon the assumption of an *endo*-transition state, and this was subsequently confirmed by conversion to the natural product. This result confirms the undesirability of the alkyne in the earlier studies (Table 1).

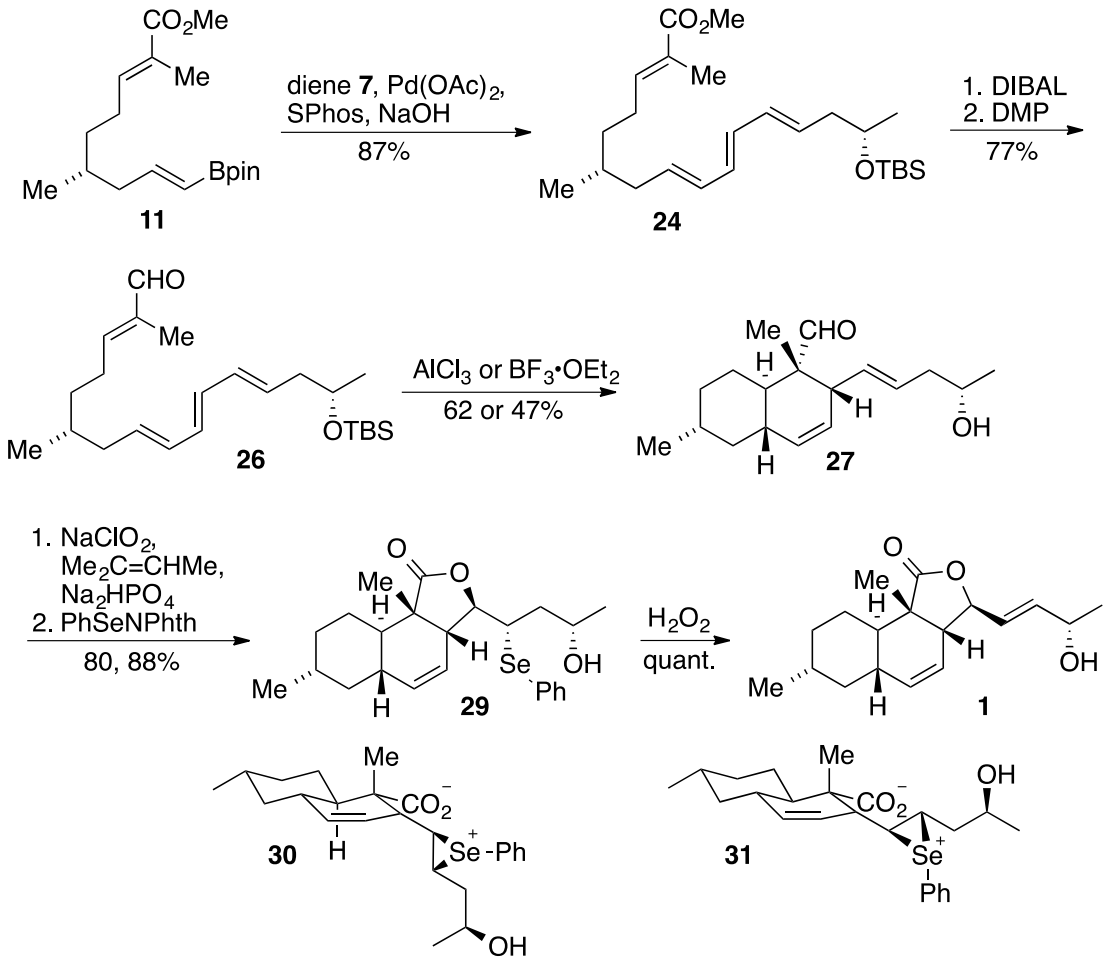
Table 1. Diels-Alder reactions



entry	R, R’	diene subst.	Lewis acid	T/ °C	time	product, yield	ratio
1	CHO, Me	yne	Me_3Al	0	o.n.	**15** 0	-

2	CHO, Me	yne	Me_2AlCl	-40	o.n.	**15** 20%	2:1
3	CHO, Me	yne	$AlCl_3$	-40	o.n.	**15** 30%	2:1
4	CHO, Me	yne	$BF_3•OEt_2$	-40	o.n.	**15** dec.	-
5	$(CO_2Me)_2$	yne	$AlCl_3$	-78	o.n.	**22** 42%	2:1
6	Meldrum's	yne	-	-	-	**23** 82%	2:1
7	CHO, Me	ene	$BF_3•OEt_2$	-40	o.n.	**27** 47%	>95:5
8	CHO, Me	ene	$BF_3•OEt_2$	0	1 hr	**27** 47%	>95:5
9	CHO, Me	ene	Me_2AlCl	-40	o.n.	**27** ND	>95:5
10	CHO, Me	ene	$AlCl_3$	0	1 hr	**27** 62%	>95:5

Pinnick oxidation of aldehyde **27** gave carboxylic acid **28**, the substrate for cyclofunctionalisation to form the lactone. While iodocyclisation ($NaHCO_3$, I_2)[18-20] proved to be completely stereoselective, attempts to eliminate the iodide under basic conditions gave an inseparable mixture of alkene regioisomers. A similar observation has been made by Bartlett.[33] Selenocyclisation using *N*-phenylselenylphthalimide[34] also proceeded smoothly and with complete stereoselectivity. Elimination of selenium from lactone **29** occurred cleanly and with complete regioselectivity after oxidation with hydrogen peroxide, to give allahabadolactone A **1**. The melting point (116-117 °C; lit. 117.3-118.7 °C), ^1H and ^{13}C NMR data for the synthetic material were in excellent agreement with those reported by Sadorn *et al.*.[1] This indicates that the selenocyclisation occurred with the desired stereoselectivity. Presumably the conformation of intermediate **30** leading to the unobserved isomer is precluded due to unfavourable steric interactions, but this is not the case for the diastereoisomeric intermediate **31**. The optical rotation recorded for our material (+25.9, c = 0.08, $CHCl_3$) is in excellent agreement with that reported[1] (+26.6, c = 0.13, $CHCl_3$), confirming the assigned absolute stereochemistry.



Scheme 5. The Final Diels-Alder Approach and the Completion of the Synthesis

Conclusion

While the intramolecular Diels-Alder reaction route to molecules of this type has been extensively used, our results show that a small change in the diene substituent can have a profound effect. In particular, a dienyne and a triene give significantly different results in terms of the stereochemical outcome. Combining rapid triene construction by coupling of *trans*-1,2-dichloroethylene, the intramolecular Diels-Alder reaction and a highly efficient selenocyclisation-elimination procedure that is both stereo and regioselective, this work constitutes, to the best of our knowledge, the first synthesis of allahabadolactone A **1**. The synthesis requires a total of 10 steps from citronellal and provides an overall yield of 13%.

Experimental

When appropriate, reactions were run under a nitrogen atmosphere in oven-dried glassware. THF and ether were distilled from sodium/ benzophenone, toluene was distilled from sodium and dichloromethane was distilled from calcium hydride. The other solvents and reagents were used as received. Column chromatography was carried out on silica gel 230-400 mesh, and analytical TLC on glass plates (silica gel 60, F_{254}). NMR spectra were recorded in $CDCl_3$ solutions at 400 MHz (^1H) or 100 MHz (^{13}C). Chemical shifts are recorded in ppm and

coupling constants are recorded in Hz. HRMS measurements were recorded using a TOF mass analyser.

*(S,E)-7-Chlorohept-6-en-4-yn-2-ol (**4**)*. A solution of *trans*-1,2-dichloroethene (276 μL, 3.66 mmol), alcohol **3** (200 mg, 2.38 mmol), $Pd(PPh_3)_4$ (69 mg, 2.5 mol%), CuI (23 mg, 5 mol%) and Et_3N (663 μL, 4,76 mmol) in anhydrous THF (10 mL) was stirred overnight under N_2. The reaction was quenched with aq. NH_4Cl (10 mL) and the mixture was extracted with Et_2O (10 mL × 3). The combined organic layers were washed with brine, dried ($MgSO_4$) and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel (20% EtOAc/Hexane) to give enynol **4** as a colorless oil (326 mg, 95 %); $[\alpha]_D^{23}$ +12.5 (*c* 3.00, $CHCl_3$); IR(neat) cm^{-1}: 3372, 3073, 2907, 2220, 1718; ^1H NMR (400 MHz, $CDCl_3$) δ 6.49 (d, J=13.7 Hz, 1H), 5.92 (dt, J=13.7, 2.3 Hz, 1H), 3.97 (sex, J=6.4 Hz, 1H), 2.52 (ddd, J=16.9, 6.0, 2.3 Hz, 1H), 2.44 (ddd, J=16.9, 6.4, 2.3 Hz, 1H), 1.27 (d, J=6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 130.0, 114.0, 89.5, 78.1, 66.5, 30.1, 22.6; MS (ESI): *m/z* = 145.19 $[C_7H_{19}O^{35}Cl+H]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_7H_{10}O^{35}Cl$: 145.0420; found: 145.0414.

*(S,4E,6E)-7-Chlorohepta-4,6-dien-2-ol (**5**)*. Red-Al (3.36 mL, 11.19 mmol, 65% wt. in tol.) was slowly added to a solution of alcohol **4** (1.20 g, 8.30 mmol) in anhydrous THF (15 mL) at -78 ºC and then the reaction was heated at reflux for 3 h. The mixture was cooled to 0 ºC and quenched with H_2O. After adding HCl (5 ml, 2M), the mixture was extracted with Et_2O (10 mL × 3). The combined organic layers were washed with brine and dried over Na_2SO_4. After removal of the solvent under reduced pressure, the residue was purified by flash chromatography on silica gel (20% EtOAc/Hexane) to give the dienol **5** as a colorless oil (1.12 g, 92 %); $[\alpha]_D^{23}$ +12.9 (*c* 1.00, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 6.44 (dd, J=13.3, 10.6 Hz, 1H), 6.14 (d, J= 13.3 Hz, 1H), 6.07 (dd, J= 15.6, 11.0 Hz, 1H), 5.71 (dt, J= 15.6, 7.3 Hz, 1H), 3.85 (sex, J=6.4 Hz, 1H), 2.31-2.17 (m, 2H), 1.21 (d, J=6.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 133.6, 131.5, 129.5, 120.0, 67.5, 42.7, 23.2; IR(neat) cm^{-1}: 3372, 2970, 2928, 1653, 1583; MS (ESI): *m/z* = 147.27 $[C_7H_{11}O^{35}Cl+H]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_7H_{12}O^{35}Cl$: 147.0577; found: 147.0573.

*(S,E)-t-Butyl((7-chlorohept-6-en-4-yn-2-yl)oxy)dimethylsilane (**6**)*. A solution of alcohol **4** (237 mg, 1.64 mmol), TBSCl (299 mg, 1.99 mmol) and imidazole (226 mg, 3.32 mmol) in CH_2Cl_2 (10 mL) was stirred at room temperature for 2 h. After quenching with aq. NH_4Cl, the mixture was extracted with Et_2O (10 mL x 3). The combined organic solution was washed with brine, dried (Na_2SO_4) and filtered through celite. The volatiles were removed under reduced pressure and the residue was purified by flash chromatography (25% EtOAc/Hexane) to give enyne **6** as a colorless oil (399 mg, 94%); $[\alpha]_D^{23}$ +12.3 (*c* 0.30, $CHCl_3$); IR(neat) cm^{-1}: 2955, 2856, 2220, 1699, 1585; ^1H NMR (400 MHz, $CDCl_3$) δ 6.44 (d, J=14, 1H), 5.91 (dt, J=14.0, 2.3 Hz, 1H), 3.5 (sex, J=6.4 Hz, 1H), 2.45 (ddd, J=16.5, 6.0, 2.3 Hz, 1H), 2.34 (ddd, J=16.5, 6.8, 1.8 Hz, 1H), 1.21 (d, J=5.9 Hz, 3H), 0.89 (s, 9H), 0.07 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 129.2, 114.4, 91.1, 67.7, 30.5, 26.0, 23.8, -4.7; MS (ESI): *m/z* = 259.50 $[M + H]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_{13}H_{24}OSi^{35}Cl$: 259.1285; found: 259.1294.

*t-Butyl(((S,4E,6E)-7-chlorohepta-4,6-dien-2-yl)oxy)dimethylsilane (**7**)*. A solution of alcohol **5** (240 mg, 1.64 mmol), TBSCl (299 mg, 1.99 mmol) and imidazole (226 mg, 3.32 mmol) in CH_2Cl_2 (10 mL) was stirred at room tempertaure for 2 h. The reaction was quenched with aq. NH_4Cl (10 mL) and the mixture was extracted with Et_2O (10 mL × 3). The combined organic layers were washed with brine, dried over $MgSO_4$ and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel (10% EtOAc/Hexane) to give diene **7** as a colorless oil (397 mg, 93%); $[\alpha]_D^{23}$ +12.0 (*c* 0.20, $CHCl_3$); IR(neat) cm^{-1}: 3422, 2955, 2857, 2100, 1653, 1638; ^1H NMR (400 MHz, $CDCl_3$) δ 6.42 (dd, J=13.3, 11.0 Hz, 1H), 6.09 (d, J=13.3 Hz, 1H), 5.99 (dd, J=15.6, 11.0 Hz, 1H), 5.70 (dt, J=15.1, 7.3 Hz, 1H), 3.87-3.80 (sex, J=6.4, 1H), 2.25-2.13 (m, 2H), 1.12 (d, J=6.0 Hz, 3H), 0.88 (s, 9H), 0.04-0.03 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.0, 132.8, 128.3, 119.0, 68.6, 43.2, 26.1, 23.8, 18.4, -4.3, -4.5; MS (ESI): m/z = 261.41[$C_{13}H_{25}O^{35}Cl$ + H]$^+$; HRMS (EI): m/z [M + Na]$^+$ calcd for $C_{13}H_{25}O^{35}ClSiNa$: 283.1261; found: 283.1275.

*(R)-4,8-Dimethylnon-7-en-1-yne (**9**)*. Method A: (*R*)-Citronellal **8** (1.00 g, 6.48 mmol) was added to a mixture of diethyl (1-diazo-2-oxopropyl)phosphonate (1.87 g, 9.72 mmol) and K_2CO_3 (1.79 g, 13.0 mmol) in methanol (15 mL). The mixture was stirred overnight at room temperature. The solvent was removed under reduced pressure and H_2O (20 mL) was added. The mixture was extracted with Et_2O (20 mL × 3). The combined organic layers were washed with brine, dried ($MgSO_4$) and the solvent was removed under reduced pressure. The residue was purified by flash chromatography on silica gel (10% EtOAc/Hexane) to afford alkyne **9**[27] as a colorless oil (0.71 g, 73%); Method B: PPh_3 (3.40 g, 12.96 mmol), Zn power (848 mg, 12.96 mmol) and CBr_4 (4.30 g, 12.96 mmol) was mixed in anhydrous CH_2Cl_2 (40 mL). The mixture was stirred overnight at room temperature under N_2. (*R*)-citronellal **8** (1.00 g, 6.48 mmol) was added to the mixture and the reaction was stirred for 2 h and then quenched with H_20 (30 mL). The layers were extracted with CH_2Cl_2 (20 mL × 3). The combined organic layers were washed with brine, dried over Na_2SO_4 and concentrated *in vacuo*. The crude was purified by flash chromatography on silica gel to give a colorless oil (1.88 g, 94%). The oil was dissolved in anhydrous THF (15 mL) and the reaction was cooled to -78 °C. *n*-BuLi (7.6 mL, 12.16 mmol, 1.6 M in hexane) was added dropwise to the reaction. After stirring for 2 h at -78 ºC, the reaction was quenched with H_2O and warmed to room temperature. The mixture was extracted with Et_2O (10 mL × 3). The combined organic layers were washed with brine and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (10% EtOAc/Hexane) to give alkyne **9**[27] as a colorless oil (0.82 g, 90%); ^1H NMR (400 MHz, $CDCl_3$) δ 5.12-5.08 (m, 1H), 2.17 (ddd, J=16.5, 5.5, 2.8 Hz, 1H), 2.07 (ddd, J=16.5, 6.9, 2.8 Hz, 1H), 2.02-1.94 (m, 3H), 1.70-1.66 (m, 4H), 1.61 (s, 3H), 1.49-1.41 (m, 1H), 1.29-1.19 (m, 1H), 1.00 (d, J=6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 131.7, 124.7, 83.6, 69.3, 36.2, 32.2, 26.0, 25.9, 25.8, 19.5, 17.9.

*Methyl (R,E)-2,6-dimethylnon-2-en-8-ynoate (**10**)*. Alkyne **10** was prepared according to our procedure reported previously for the racemic compound;[23] $[\alpha]_D^{23}$ +4.1 (*c* 0.68, $CHCl_3$).

*Methyl (R,2E,8E)-2,6-dimethyl-9-(4,4,5,5-tetramethyl-1,3,2- dioxaborolan-2-yl) nona-2,8-dienoate (**11**)*. Boronate **11** was prepared according to our procedure reported previously for the racemic compound;[23] $[\alpha]_D^{23}$ -1.8 (*c* 3.50, $CHCl_3$).

*Methyl (2E,8E,10E,15S)-15-((t-Butyldimethylsilyl)oxy)-2,6-dimethylhexadeca-2,8,10-trien-12-ynoate (**12**)*. Trienyne **12** was prepared in 88% yield from alkenyl boronate **11** and enyne **6** according to the procedure described for tetraene **24**; IR(neat) cm^{-1}: 2955, 2929, 2737, 2253, 2214, 1715, 1653; ^1H NMR (400 MHz, $CDCl_3$) δ 6.73 (t, J=7.2 Hz, 1H), 6.45 (dd, J=15.6, 10.8 Hz, 1H), 6.04 (dd=15.6, 10.8 Hz, 1H), 5.70 (dt, J=15.6, 7.2 Hz, 1H), 5.48 (d, J=15.6 Hz, 1H), 3.97-3.93 (m, 1H), 3.73 (s, 3H), 2.52-2.33 (m, 3H), 2.19-1.92 (m, 4H), 1.83 (s, 3H), 1.62-1.39 (m, 2H), 1.29-1.22 (m, 3H), 0.89-0.78 (m, 12H), 0.08 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 142.8, 141.1, 135.3, 131.5, 127.7, 109.9, 90.0, 81.5, 68.2, 51.9, 40.3, 35.5, 33.1, 30.8, 26.5, 26.1, 23.7, 19.6, 18.4, 12.6, -4.5; MS (ESI): *m/z* = 419.34 $[M + H]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_{25}H_{43}O_3Si$: 419.2981; found: 419.2998.

*(2E,8E,10E,15S)-15-((t-Butyldimethylsilyl)oxy)-2,6-dimethylhexadeca-2,8,10-trien-12-yn-1-ol (**13**)*. Trienyne **13** was prepared in 72% yield from trienyne **12** according to the procedure described for alcohol **25**; IR(neat) cm^{-1}: 3412, 2955, 2929, 2258, 1654; ^1H NMR (400 MHz, $CDCl_3$) δ 6.48 (dd, J=15.6, 11.0 Hz, 1H), 6.04 (dd=15.1, 11.0 Hz, 1H), 5.70 (dt, J=15.1, 7.2 Hz, 1H), 5.47 (d, J=15.6 Hz, 1H), 5.38 (t, J=7.4 Hz, 1H), 3.99-3.3.91 (m, 3H), 2.52-2.32 (m, 2H), 2.13-1.89 (m, 4H), 1.66 (s, 3H), 1.59-1.28 (m, 3H), 1.23-1.08 (m, 6H), 0.87 (s, 9H), 0.07 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.2, 135.7, 134.9, 131.3, 126.6, 109.6, 89.9, 81.4, 69.2, 68.2, 40.4, 36.5, 33.0, 30.8, 26.1, 25.4, 23.7, 19.7, 18.4, 13.9, -4.4; MS (ESI): *m/z* = 391.73 $[M + H]^+$; HRMS (EI): *m/z*$[M + H]^+$ calcd for $C_{24}H_{43}O_2Si$: 391.3032; found: 391.3070.

*(2E,8E,10E,15S)-15-((t-Butyldimethylsilyl)oxy)-2,6-dimethylhexadeca-2,8,10-trien-12-ynal (**14**)*. Aldehyde **14** was prepared in 90% yield from alcohol **13** according to the procedure described for aldehyde **26**; IR(neat) cm^{-1}: 2953, 2723, 2216, 1732, 1695, 1568; ^1H NMR (400 MHz, $CDCl_3$) δ 9.39 (s, 1H), 6.51-6.45 (m, 2H), 6.05 (dd, J=15.1, 11.0 Hz, 1H), 5.72 (dt, J=15.1, 7.2 Hz, 1H), 5.49 (d, J=15.6 Hz, 1H), 3.98-3.91 (m, 1H), 2.52-2.33 (m, 4H), 2.18-1.93 (m, 2H), 1.74 (s, 3H), 1.67-1.48 (m, 3H), 1.28-1.18 (m, 6H), 0.89 (s, 9H), 0.08 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.4, 154.9, 140.9, 139.4, 134.8, 131.6, 110.0, 90.0, 81.3, 68.1, 40.2, 35.1, 33.1, 26.8, 26.0, 23.6, 19.5, 18.3, 9.3, -4.5; MS (ESI): *m/z* = 389.62 $[M + H]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_{24}H_{41}O_2Si$: 389.2876; found: 389.2879.

*(±)-4-Methylhept-6-yn-1-ol (**16**)*. O_3 in O_2 was bubbled through a solution of alkyne **9** (1.00 g, 6.65 mmol) in MeOH (40 mL) at room temperature. When all the starting material was consumed, O_2 was flushed through the solution for 10 min. The mixture was cooled to 0 °C and $NaBH_4$ was added portionwise. The reaction was stirred for 30 min before aq. NH_4Cl (5 mL) was added. The mixture was concentrated in vacuo and the mixture was extracted with CH_2Cl_2 (10 mL x 3). The combined organic layers were washed with brine and dried ($MgSO_4$). The volatiles were removed under reduced pressure and the residue was purified by flash chromatography on silica gel (25% EtOAc/Hexane) to give alcohol **16**[35]

(705 mg, 84%) as a colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.65 (t, J=6.4 Hz, 2H), 2.21-2.07 (m, 2H), 1.96 (t, J=2.3 Hz, 1H), 1.75-1.48 (m, 4H), 1.38-1.23 (m, 1H), 1.00 (d, J=6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 83.3, 69.5, 63.4, 32.5, 32.1, 30.5, 26.0, 19.6; all data are consistent with that reported.

*(±)- (E)-4-Methyl-7-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)hept-6-en-1-ol (**17**)*. Tri(2-furyl)phosphine (18.4 mg, 0.08 mmol) and $[Rh(CO)_2Cl]_2$ (15.4 mg, 0.04mmol) were mixed in toluene (40 mL) at room temperature under N_2. A solution of alcohol **16** (500 mg, 3.96 mmol) in toluene (2 mL) and 4,4,5,5-tetramethyl-1,3,2-dioxaborolane (0.69 mL, 4.80 mmol) was added. The mixture was stirred for 2 h at room temperature. The reaction was quenched with H_2O and the mixture was extracted with Et_2O (10 mL x 3). The combined organic layers were washed with brine, dried over $MgSO_4$ and concentrated *in vacuo*. The residue was purified by flash chromatography (25% EtOAc/Hexane) to give alkenyl boronate **17** as a colorless oil (886 mg, 88%); IR(neat) cm^{-1}: 3397, 2976, 2929, 2870, 2247, 1734, 1636; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.59 (dt, J=18.0, 6.9 Hz, 1H), 5.42 (d, J=18.0 Hz, 1H), 3.64-3.60 (m, 2H), 2.21-2.14 (m, 1H), 2.05-1.97 (m, 1H), 1.64-1.48 (m, 4H), 1.43-1.34 (m, 1H), 1.26 (s, 12H), 0.90 (d, J=6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.4, 83.3, 63.5, 43.8, 32.8, 30.6, 25.0, 19.8; MS (ESI): *m/z* = 255.32 $[M + H]^+$; HRMS (EI): *m/z* $[M + Na]^+$ calcd for $C_{14}H_{27}BO_3Na$: 277.1951; found: 277.1933.

*(6E,8E,13S)-13-((t-Butyldimethylsilyl)oxy)-4-methyltetradeca-6,8-dien-10-yn-1-ol (**18**)*. A solution of alcohol **17** (500 mg, 1.76 mmol), vinyl chloride **6** (455 mg, 1.76 mmol), $Pd(OAc)_2$ (8 mg, 0.035 mmol), Sphos (29 mg, 0.070 mmol) and NaOH (142 mg, 3.52 mmol) in THF/H_2O (20 mL, 1:1) was stirred at 70 °C for 2 h. The mixture was cooled to room temperature and extracted with Et_2O (10 mL x 3). The combined organic layers were washed with brine, dried (Na_2SO_4) and filtered through celite. The solution was concentrated *in vacuo* and the residue was purified by flash chromatography (25% EtOAc/Hexane) to give dienyne **18** as a colorless oil (502 mg, 85%); IR(neat) cm^{-1}: 3421, 3053, 2929, 2856, 2304, 2123, 1637; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.48 (dd, J=15.6, 11.0 Hz, 1H), 6.05 (dd, J=15.1, 11.0 Hz, 1H), 5.72 (dt, J=15.1, 7.3 Hz, 1H), 5.47 (d, J=15.6 Hz, 1H), 3.98-3.93 (m, 1H), 3.62 (t, J=6.4 Hz, 2H), 2.49 (ddd, J=16.9, 5.9, 2.3 Hz, 1H), 2.36 (ddd, J=16.5, 6.9, 2.3 Hz, 1H), 2.14-2,08 (m, 1H), 1.99-1.92 (m, 1H), 1.64-1.48 (m, 4H), 1.42-1.20 (m, 7H), 0.89 (s, 9H), 0.07 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.2, 135.6, 131.4, 109.7, 89.9, 81.5, 68.2, 63.5, 40.5, 33.3, 32.8, 30.8, 30.6, 26.1, 23.7, 19.7, 18.4, -4.4; MS (ESI): *m/z* = 351.59 $[M + H]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_{21}H_{39}O_2Si$: 351.2719; found: 351.2715.

*(6E,8E,13S)-13-((t-Butyldimethylsilyl)oxy)-4-methyltetradeca-6,8-dien-10-ynal (**19**)*. A solution of alcohol **18** (900 mg, 2.58 mmol) and DMP (1.63 g, 3.87 mmol) in CH_2Cl_2 (20 mL) was stirred at room temperature for 30 min. After quenching with aq. $NaHCO_3$ (20 mL), the mixture was extracted with CH_2Cl_2 (10 mL x 3). The combined organic layers were washed with brine, dried ($MgSO_4$), filtered through celite and concentrated *in vacuo*. The residue was purified by flash chromatography (25% EtOAc/Hexane) to give aldehyde **19** (842 mg, 94%) as a colorless oil; IR(neat) cm^{-1}: 2957, 2928, 2904, 2856, 2719, 2150, 1724, 1638; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.76 (t, J=1.8 Hz, 1H), 6.48 (dd, J=15.6, 11.0 Hz, 1H),

6.06 (dd, J=15.1, 11.0 Hz, 1H), 5.70 (dt, J=15.1 Hz, 7.3 Hz, 1H), 5.49 (d, J= 15.6 Hz, 1H), 3.98-3.92 (m, 1H), 2.52-2.33 (m, 4H), 2.14- 2.07 (m, 1H), 2.01-1.94 (m, 1H), 1.72- 1.39 (m, 3H), 1.22 (d, J=6.0 Hz, 3H), 0.89 (s, 9H), 0.07 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.8, 141.0, 134.8, 131.7, 110.1, 90.1, 81.4, 68.2, 41.9, 40.2, 33.0, 30.8, 28.7, 26.1, 23.7, 19.5, 18.4, -4.5; MS (ESI): m/z = 349.67 $[M + H]^+$; HRMS (EI): m/z $[M + H]^+$ calcd for $C_{21}H_{37}O_2Si$: 349.2563; found: 349.2594.

*Dimethyl 2-((6E,8E,13S)-13-((t-butyldimethylsilyl)oxy)-4-methyltetradeca- 6,8-dien-10-yn-1-ylidene)malonate (**20**)*. A solution of aldehyde **19** (500 mg, 1.50 mmol), dimethyl malonate (165 µL, 1.50 mmol), piperidine (30 µL, 0.30 mmol) and AcOH (17 µL, 0.30 mmol) in CH_2Cl_2 (10 mL) was stirred for 4 h at room temperature. The solvent was removed under reduce pressure. H_2O (5 mL) was added and the mixture was extracted with Et_2O (5 mL x 3). The combined organic layers were washed with aq. $NaHCO_3$, brine and dried over $MgSO_4$. The volatiles were removed *in vacuo* and the residue was purified by flash chromatography (25% EtOAc/Hexane) to give alkylidene malonate **20** as a colorless oil (500 mg, 75%); IR(neat) cm^{-1}: 3022, 2953, 2928, 2857, 2081, 1732, 1688, 1643; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.01 (t, J=8.2 Hz, 1H), 6.47 (dd, J=15.6, 11.0 Hz, 1H), 6.05 (dd, J=15.1, 11.0 Hz, 1H), 5.69 (dt, J=15.1 Hz, 7.3 Hz, 1H), 5.48 (d, J=15.6 Hz, 1H), 3.97-3.93 (m, 1H), 3.82 (s, 3H), 3.78 (s, 3H), 2.51-2.27 (m, 4H), 2.11-2.04 (m, 1H), 1.97-1.93 (m, 1H), 1.57-1.43 (m, 2H), 1.32-1.22 (m, 7H), 0.89 (s, 9H), 0.07 (s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.3, 164.6, 150.7, 141.0, 135.0, 131.7, 127.9, 110.0, 89.8, 81.2, 68.2, 52.6, 52.5, 40.2, 35.1, 33.0, 30.8, 27.7, 26.1, 23.7, 19.5, 18.4, -4.5; MS (ESI): m/z = 463.68 $[M + H]^+$; HRMS (EI): m/z $[M + H]^+$ calcd for $C_{26}H_{43}O_5Si$: 463.2880; found: 463.2866.

*2-((S)-4-((t-Butyldimethylsilyl)oxy)pent-1-yn-1-yl)-2',2',6-trimethyl-4a,5,6,7,8,8a-hexahydro-2H-spiro[naphthalene-1,5'-[1,3]dioxane]-4',6'-dione (**23**)*. A solution of Meldrum's acid (365 mg, 2.53 mmol), aldehyde **19** (840 mg, 2.41 mmol) piperidine (48 µL, 0.48 mmol) and AcOH (28 µL, 0.48 mmol) in CH_2Cl_2 (10 mL) was stirred for 2h at room temperature. The solvent was removed under reduced pressure. H_2O (10 mL) was added and the mixture was extracted with Et_2O (10 mL x 3). The combined organic layers were washed with aq. $NaHCO_3$, brine and dried ($MgSO_4$). The solvent was removed under reduced pressure and the residue was purified by flash chromatography (25% EtOAc/Hexane) to give tricycle **23** as a colorless oil (942 mg, 82%, 2:1 mixture of diastereoisomers); ^{1}H NMR (major isomer) (400 MHz, $CDCl_3$) δ 5.68 (d, J=10.1 Hz, 1H), 5.64-5.60 (m, 1H), 3.93-3.88 (m, 1H), 3.58 (s, 1H), 2.25-2.17 (m, 2H), 2.00-1.86 (m, 2H), 1.64-1.54 (m, 3H), 1.73 (s, 3H), 1.72 (s, 3H), 1.27-1.16 (m, 7H), 0.89-0.82 (m, 2H), 0.05 (s, 6H).

*Methyl (2E,6R,8E,10E,12E,15S)-15-((t-butyldimethylsilyl)oxy)-2,6-dimethylhexadeca-2,8,10,12-tetraenoate (**24**)*. A solution of vinyl chloride **7** (500 mg, 1.92 mmol), boronate **11** (620 mg, 1.92 mmol), NaOH (155 mg, 3.84 mmol), $Pd(OAc)_2$ (8.8 mg, 0.038 mmol) and Sphos (30 mg, 0.076 mmol) in THF/H_2O (20 mL, 1:1) was heated at 70 °C for 2 h under N_2. Aq. NH_4Cl (5 mL) was added and the mixture was extracted with Et_2O (10 mL × 3). The combined organic layers were washed with brine, dried ($MgSO_4$) and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (10% EtOAc/Hexane) to give

tetraene **24** as a colorless oil (704 mg, 87%); $[\alpha]_D^{23}$ +7.9 (*c* 1.80, $CHCl_3$); IR(neat) cm^{-1}: 3419, 2953, 2928, 2857, 2360, 1717, 1647; ^1H NMR (400 MHz, $CDCl_3$) δ 6.74 (t, J=7.8 Hz, 1H), 6.11-5.98 (m, 4H), 5.68-5.59 (m, 2H), 3.86-3.80 (m, 1H), 3.73 (s, 3H), 2.28-2.07 (m, 4H), 2.00-1.93 (m, 1H), 1.83 (s, 3H), 1.55-1.43 (m, 2H), 1.30-1.19 (m, 2H), 1.12 (d, J=6.0 Hz, 3H), 0.94-0.83 (m, 12H), 0.04-0.03 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 142.9, 132.8, 132.7, 132.2, 131.3, 131.2, 131,1, 127.7, 69.0, 51.9, 43.5, 40.4, 35.4, 33.2, 26.5, 26.1, 23.8, 19.6, 18.4, 12.6, -4.3, -4.4; MS (ESI): *m/z* = 443.61 $[M + Na]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_{25}H_{45}O_3Si$: 421.3138; found: 421.3140.

*(2E,6R,8E,10E,12E,15S)-15-((t-Butyldimethylsilyl)oxy)-2,6-dimethylhexadeca-2,8,10,12-tetraen-1-ol (**25**)*. DIBAL-H (2.15 mL, 2.15 mmol, 1 M in cyclohexane) was added slowly to a solution of the ester **24** (600 mg, 1.43 mmol) in CH_2Cl_2 (20 mL) at -78 °C. After stirring overnight at -78 °C, aqueous potassium sodium tartrate solution (1.21 g, 5 mL) was added to the mixture. The solution was allowed to warm to room temperature and stirred for 2 h further, then extracted with CH_2Cl_2 (10 mL × 3). The combined organic layers were washed with brine, dried ($MgSO_4$) and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (50% EtOAc/Hexane) to give alcohol **25** as a colorless oil (432 mg, 77%); $[\alpha]_D^{23}$ +9.0 (*c* 0.80, $CHCl_3$); IR(neat) cm^{-1}: 3356, 3013, 2955, 2928, 1689, 1644, 1641; ^1H NMR (400 MHz, $CDCl_3$) δ 6.11-6.00 (m, 4H), 5.68-5.60 (m, 2H), 5.39 (t, J=7.3 Hz, 1H), 3.99 (d, J=5.0 Hz, 2H), 3.84-3.79 (m, 1H), 2.24-1.93 (m, 6H), 1.66 (s, 3H), 1.57-1.24 (m, 3H), 1.12 (d, J=6.0 Hz, 3H), 0.89-0.84 (m, 12H), 0.04-0.03 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 134.8, 133.2, 132.7, 132.0, 131.4, 131.1, 131.0, 126.8, 69.3, 69.0, 43.5, 40.5, 36.5, 33.2, 26.1, 25.4, 23.8, 19.7, 18.4, 13.9, -4.3, -4.4;MS (ESI): *m/z* = 393.35 $[M + H]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_{24}H_{45}O_2Si$: 393.3189; found: 393.3182.

*(2E,6R,8E,10E,12E,15S)-15-((t-Butyldimethylsilyl)oxy)-2,6-dimethylhexadeca-2,8,10,12-tetraenal (**26**)*. DMP (1.86 g, 4.38 mmol) was added to a solution of alcohol **25** (860 mg, 2.19 mmol) in CH_2Cl_2 (20 mL) and the mixture was stirred for 30 min at room temperature. The reaction was quenched with aq. $NaHCO_3$ (20 mL) and the mixture was extracted with CH_2Cl_2 (10 mL × 3). The combined organic layers were dried ($MgSO_4$) and filtered through celite. The solvent was removed under reduced pressure and the residue was purified by flash chromatography on silica gel (20% EtOAc/Hexane) to give aldehyde **26** as a colorless oil (780 mg, 91%); $[\alpha]_D^{23}$ +14.0 (*c* 0.80, $CHCl_3$); IR(neat) cm^{-1}: 3422, 2957, 2928, 2857, 1726, 1690, 1639, 1462, 1375; ^1H NMR (400 MHz, $CDCl_3$) δ 9.39 (s, 1H), 6.47 (t, J=7.3 Hz, 1H), 6.12-6.02 (m, 4H), 5.69-5.61 (m, 2H), 3.86-3.80 (m, 1H), 2.38-1.98 (m, 5H), 1.75 (s, 3H), 1.60-1.49 (m, 2H), 1.32-1.23 (m, 2H), 1.12 (d, J=5.9 Hz, 3H), 0.95-0.87 (m, 12H), 0.07-0.03 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.6, 155.2, 139.4, 132.6, 132.5, 132.4, 131.4, 131.3, 131.2, 68.9, 43.5, 40.4, 35.2, 33.3, 26.9, 26.1, 23.8, 19.6, 18.4, 9.4, -4.3, -4.4; MS (ESI): *m/z* = 413.62 $[M + Na]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_{24}H_{43}O_2Si$: 391.3032; found: 391.3037.

*(1S,2R,4aS,6R,8aR)-2-((S,E)-4-Hydroxypent-1-en-1-yl)-1,6-dimethyl-1,2,4a,5,6,7,8,8a-octahydronaphthalene-1-carbaldehyde (**27**)*. $AlCl_3$ (136 mg, 1.02 mmol) was added to a solution of aldehyde **26** (200 mg, 0.51 mmol) in CH_2Cl_2

(10 mL) at 0 ºC. After stirring for 1 h, the reaction was quenched with aq. $NaHCO_3$ (10 mL). The mixture was extracted with Et_2O (5 mL x 3). The combined organic layers were washed with brine and dried ($MgSO_4$). The solvent was removed in vacuo and the residue was purified by flash chromatography on silica gel (30% EtOAc/Hexane) to give bicycle **27** as a colorless oil (88 mg, 62%); $[\alpha]_D^{23}$ +211.6 (*c* 0.50, $CHCl_3$); IR(neat) cm^{-1}: 3410, 2955, 2928, 2857, 1719; ^1H NMR (400 MHz, $CDCl_3$) δ 9.49 (s, 1H), 5.54-5.36 (m, 4H), 3.82-3.76 (m, 3H), 2.61-2.58 (m, 1H), 2.23-2.08 (m, 2H), 1.85-1.39 (m, 9H), 1.17 (d, J=5.9 Hz, 3H), 1.04 (s, 3H), 0.92 (d, J=6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 209.1, 132.6, 131.6, 129.8, 126.5, 67.4, 50.7, 49.2, 42.7, 41.8, 39.1, 37.6, 35.6, 33.4, 27.2, 23.0, 22.7, 14.3; MS (ESI): *m/z* = 299.48 $[M + Na]^+$; HRMS (EI): *m/z* $[M + H]^+$ calcd for $C_{18}H_{29}O_2$: 277.2168; found: 277.2173.

*(1S,2R,4aS,6R,8aR)-2-((S,E)-4-Hydroxypent-1-en-1-yl)-1,6-dimethyl-1,2,4a,5,6,7,8,8a-octahydronaphthalene-1-carboxylic acid (**28**)*. NaH_2PO_4 (60 mg, 0.50 mmol), 2-methylbut-2-ene (172 µL, 1.62 mmol) was added to a solution of aldehyde **27** (100mg, 0.36 mmol) in *t*-BuOH/H_2O (8 mL, 3:1). $NaClO_2$ (82 mg, 0.90 mmol) was added to the mixture. The reaction was stirred for 4 h at room temperature. H_2O (10 mL) was added to the reaction, and the mixture was extracted with Et_2O (10 mL x 3). The combined organic layers were washed with brine, dried ($MgSO_4$) and the solvent was removed under reduced pressure. The acid **28** was obtained by flash chromatography on silica gel (50% EtOAc/Hexane) as a colorless oil (117 mg, 80%); $[\alpha]_D^{23}$ +114.1 (*c* 0.80, $CHCl_3$); IR(neat) cm^{-1}: 3422, 2953, 2924, 2855, 1667, 1608, 1585; ^1H NMR (400 MHz, $CDCl_3$) δ 5.50-5.35 (m, 4H), 5.09 (br, 1H), 3.82-3.72 (m, 1H), 2.61 (dd, J=8.7, 4.1 Hz, 1H), 2.24-2.17 (m, 2H), 2.02-1.97 (m,1H), 1.81-1.72 (m, 4H), 1.63-1.47 (m, 4H), 1.19-1.16 (m, 6H), 0.91 (d, J=6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.7, 135.7, 131.3, 127.6, 126.2, 67.3, 50.7, 49.6, 42.5, 42.0, 40.4, 38.3, 35.7, 33.6, 27.7, 22.7, 22.7, 16.8; MS (ESI): *m/z* = 315.48 $[M + Na]^+$; HRMS (EI): *m/z* $[M + Na]^+$ calcd for $C_{18}H_{28}O_3Na$: 315.1936; found: 315.1928.

*(3R,3aR,5aS,7R,9aR,9bS)-3-((1S,3S)-3-Hydroxy-1-(phenylselanyl)butyl)-7,9b-dimethyl-3a,5a,6,7,8,9,9a,9b-octahydronaphtho[1,2-c]furan-1(3H)-one (**29**)*. *N*-(Phenylseleno)phthalimide (123 mg, 0.42 mmol) was added to a solution of acid **28** (60 mL, 0.21 mmol) in CH_2Cl_2. After stirring for 2 h, the solvent was removed under reduced pressure and excess hexane was added. The mixture was filtered through celite and the filtrate was concentrated *in vacuo.* The residue was purified by flash chromatography (50% EtOAc/Hexane) to give selenide **29** as a colorless oil (157 mg, 83%); $[\alpha]_D^{23}$ +50.5 (*c* 0.20, $CHCl_3$); IR(neat) cm^{-1}: 3441, 2928, 2367, 2097, 1772, 1636, 1558; ^1H NMR (400 MHz, $CDCl_3$) δ 7.63-7.60 (m, 2H), 7.30-7.28 (m, 3H), 5.80-5.76 (m, 1H), 5.61 (d, J=10.1 Hz, 1H), 4.37 (dd, J=9.6, 5.0 Hz, 1H), 4.32-4.26 (m, 1H), 2.50 (dd, J=9.6, 4.6 Hz, 1H), 1.94-1.77 (m, 5H), 1.71-1.63 (m, 2H), 1.48-1.47 (m, 2H), 1.31-1.24 (m, 5H), 1.12 (s, 3H), 0.90 (d, J=6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.0, 134.7, 134.6, 129.5, 129.3, 128.1, 122.7, 85.4, 65.7, 49.4, 46.7, 45.6, 41.8, 41.3, 40.5, 36.2, 35.3, 33.0, 25.7, 24.5, 22.6, 16.1; MS (ESI): *m/z* = 471.16 $[M + Na]^+$; HRMS (EI): *m/z* $[M + Na]^+$ calcd for $C_{24}H_{32}O_3SeNa$: 471.1414; found: 471.1427.

*Allahabadolactone A (**1**)*. H_2O_2 (2 mL, 30% in H_2O) was added in to a solution of selenide **29** (157 mg, 0.35 mmol) in THF (5 mL). The mixture was stirred for 1 h at room temperature. After adding H_2O (5 mL), the mixture was extracted with Et_2O (5 mL x 3). The combined organic layers were washed with brine, dried ($MgSO_4$) and concentrated under reduced pressure. The residue was purified by flash chromatography (25% EtOAc/Hexane) to give Allahabadolactone A **1**[1] as a colorless solid (50 mg, 100%); m.p. 116 – 117 °C; $[\alpha]_D^{23}$ +25.9 (*c* 0.08, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 5.91 (dd, J=15.6, 5.5 Hz, 1H), 5.72 (ddd, J=15.6, 7.3, 1.3 Hz, 1H), 5.66 (d, J=10.1 Hz, 1H), 5.55-5.49 (m, 1H), 4.47 (dd, J=10.2, 7.3 Hz, 1H), 4.39-4.35 (m, 1H), 2.35-2.32 (m, 1H), 1.95-1.78 (m, 4H), 1.53-1.41 (m, 1H), 1.31-1.20 (m, 1H), 1.30 (d, J=6.8 Hz, 3H), 1.14 (s, 3H), 0.91 (d, J=6.4 Hz, 3H), 0.97-0.76 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 179.5, 139.1, 135.2, 126.1, 121.0, 82.8, 68.0, 51.7, 44.9, 41.8, 40.3, 36.4, 35.3, 33.0, 25.7, 23.5, 22.6, 16.5.

Acknowledgements
We thank the Agency for Science Technology and Research (A-Star) for financial support of this work (PSF grant number 1321202095).

Supporting Information Available
^1H and ^{13}C NMR spectra for compounds **4** - **7**, **9** - **20**, **23** - **29**, **1**.

References
1. Sadorn, K.; Saepua, S.; Boonyuen, N.; Laksanacharoen, P.; Rachtawee, P.; Prabpai, S.; Kongsaeree, P.; Pittayakhanjonwut, P. *Tetrahedron* **2016**, *72*, 489.
2. Shing, T. K. M.; Yang, J. *J. Org. Chem.*, **1995**, *60*, 5785.
3. Burke, L. T.; Dixon, D. J.; Ley, S. V.; Rodríguez, F. *Org. Lett.* **2000**, *2*, 3611.
4. Yuki, K.; Shindo, M.; Shishido, K. *Tetrahedron Lett.* **2001**, *42*, 2517.
5. Burke, L. T.; Dixon, D. J.; Ley, S. V.; Rodríguez, F. *Org. Biomol. Chem.* **2005**, *3*, 274.
6. Yin, J.; Kong, L.; Wang, C.; Shiu, Y.; Cai, S.; Gao, S. *Chem. Eur. J.* **2013**, *19*, 13040.
7. Xu, J.; Caro-Diaz, J. E.; Trzoss, L.; Theodorakis, E. A. *J. Am. Chem. Soc.* **2012**, *134*, 5072.
8. Deng, J.; Zhu, B.; Lu, Z.; Li, A. *J. Am. Chem. Soc.* **2012**, *134*, 920.
9. Liu, C.; Zeng, Z.; Chen, R.; Jiang, X.; Wang, Y.; Zhang, Y. *Org. Lett.* **2016**, *18*, 624.
10. Lang, G.; Blunt, J. W.; Cummings, N. J.; Cole, A. L. J.; Munro, M. H. G. *J. Nat. Prod.* **2005**, *68*, 810.
11. Singh, S. B.; Zink, D. L.; Goetz, M. A.; Dombrowski, A. W.; Polishook, J. D.; Hazuda, D. J. *Tetrahedron Lett.* **1998**, *39*, 2243.
12. Kong, L.; Rao, M.; Ou, J.; Yin, J.; Lu, W.; Liu, M.; Pang, X.; Gao, S. *Org. Biomol. Chem.* **2014**, *12*, 7591.
13. Inoue, A.; Kanematsu, M.; Yoshida, M.; Shishido, K. *Tetrahedron Lett.* **2010**, *51*, 3966.
14. Klas, K.; Tsukamoto, S.; Sherman, D. H.; Williams, R. M. *J. Org. Chem.* **2015**, *80*, 11672.
15. Craig, D. *Chem. Soc. Rev.* **1987**, *16*, 187.
16. Takao, K.; Munakata, R.; Tadano, K. *Chem. Rev.* **2005**, *105*, 4779.
17. Nicolaou, K. C.; Snyder, S. A.; Montagnon, T.; Vassilikogiannakis, G. *Angew. Chem. Int. Ed.* **2002**, *41*, 1668.
18. Cardillo, G.; Orena, M. *Tetrahedron* **1990**, *46*, 3321.

19. Frederickson, M.; Grigg, R. *Org. Prep. Proced. Int.* **1997**, *29*, 33.
20. Ranganathan, S.; Muraleedharan, K. M.; Vaish, N. K.; Jayaraman, N. *Tetrahedron* **2004**, *60*, 5273.
21. Bates, R. W.; Maiti, T. B. *Syn. Comm.*, **2003**, 633.
22. Ratovelomanana, V.; Linstrumelle, G. *Tetrahedron Lett.* **1981**, *22*, 315.
23. Wang, K.; Bates, R. W. *Synthesis*, **2017**, *49,* 2749.
24. Racemic citronellal was used for early studies, hence compounds **12**, **13**, **14**, **17**, **18**, **19**, **22** and **23** were prepared as mixtures of diastereoisomers. (*R*)-Citronellal was employed for the ultimately selective route.
25. Roth, G. J.; Liepold, B.; Müller, S. G.; Bestmann, H. J. *Synthesis*, **2004**, 59.
26. Corey, E. J.; Fuchs, P. L. *Tetrahedron Lett.* **1972**, *36*, 3769.
27. Fürstner, A.; Bouchez, L. C.; Funel, J.-A.; Liepins, V.; Porée, F.-H.; Gilmour, R.; Beaufils, F.; Laurich, D.; Tamiya, M. *Angew. Chem. Int. Ed.* **2007,** *46*, 9265.
28. For the Suzuki coupling of an *E*-vinyl chloride with an aryl boronic acid, see Tikad, A.; Hamze, A.; Provot, O.; Brion, J.-D.; Alami, M. *Eur. J. Org. Chem.* **2010**, 725.
29. Yates, P.; Eaton, P. *J. Am. Chem. Soc.* **1960**, *82*, 4436.
30. Inukai, T.; Kasai, M. *J. Org. Chem.* **1965**, *30*, 3567.
31. Dauben, W. G.; Kozikowski, A. P. Zimmerman, W. T. *Tetrahedron Lett.* **1975**, 515.
32. There are, to our knowledge, only a few examples of Diels-Alder reactions of alkylidene derivatives of Meldrum's acids. See, for example Zitsane, D. R.; Ravinya, I. T.; Riikure, I. A.; Tetere, Z. F.; Gudrinieste, E. Yu.; Kalei, U. O. *Russ. J. Org. Chem.* **1999**, *35*, 1457. This is , to the best of our knowledge, the first example of an intramolecular example.
33. Holmes, C. P.; Bartlett, P. A. *J. Org. Chem.* **1989**, *54*, 98.
34. Nicolaou, K. C.; Claremon, D. A.; Barnette, W. E.; Seitz, S. P. *J. Am. Chem. Soc.* **1979**, *101*, 3704.
35. Nicolaou, K. C.; Shah, A. A.; Korman, H.; Khan, T.; Shi, L.; Worawalai, W.; Theodorakis, E. A., *Angew. Chem., Int. Ed.* **2015,** *54*, 9203.