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Substituent Effects in Tandem Ring-Closing Metathesis Reactions of Dienynes

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Several dienynes bearing different substituents have been synthesized and subjected to a ring-closing metathesis (RCM) reaction using ruthenium carbene complexes. Dienynes containing a pre-existing ring and a quaternary center attached to the alkyne give the expected tandem metathesis products in high yields. For these substrates, a high selectivity for different ring sizes was achieved by modifying the reactivity of one alkene. In one case, an unusual non-metathetic activity of the second-generation Grubbs catalyst was observed and the cycloisomerization product was obtained as the major product. In the absence of favorable factors, especially when the starting substrates contain hindered alkenes, a long tether chain and/or an ester group on the alkyne part, the tandem process is slowed down or completely impeded. In these cases, dienynes behave like simple enynes and afford initial metathesis products whose further reactions give dimeric compounds.

Introduction

The tandem ring-closing metathesis (RCM) reaction[1] of dienynes, first described by Grubbs and co-workers,[2a,2b] has proved to be a powerful tool for the construction of polycyclic ring systems from acyclic starting materials. The triple bond positioned between the two olefins in substrates such as **1** acts as an olefin metathesis relay.[2c,2d] When treated with an RCM catalyst such as **2**[3] or **3**,[4] dienyne **1** undergoes an initial RCM enyne metathesis reaction[5] followed by a second ring-closing α,ω-diene metathesis reaction to produce fused bicyclic [*m*.*n*.0] systems. Depending on the length of the alkene chains, these bicyclic systems may contain five-, six-, seven-, and eight-membered rings.[6,7] In these highly efficient tandem processes, two rings are formed in a single step generally in high yields.

Multiple pathways and products are possible for these metatheses: the starting substrate can cyclize with either left-to-right or right-to-left endedness to give isomeric dienes **4** (via **A**) or **5** (via **B**; Figure 1). Therefore, site-selective initiation seems necessary for selectivity. This can be achieved by modifying the reactivity of the alkene moiety by changing steric and/or stereoelectronic factors. In general, the initial alkylidenation occurs at the more kinetically reactive alkene, which is usually the unhindered terminal monosubstituted double bond.

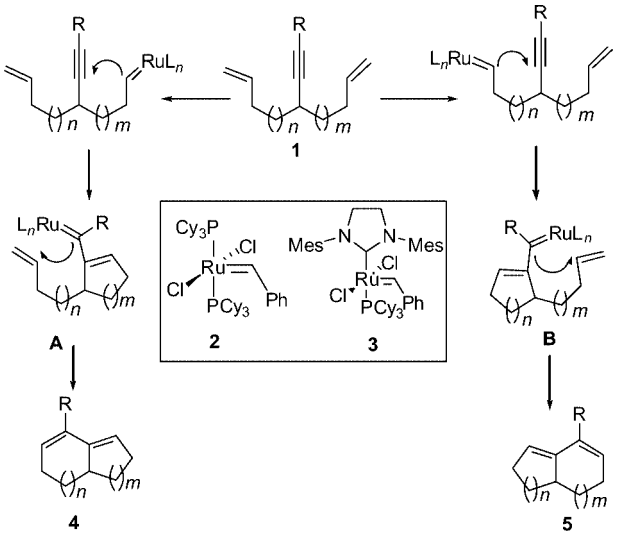

Figure 1. Two possible reaction pathways of dienyne metathesis.

In a previous report, we described the application of this technique for the preparation of polyoxygenated fused bicyclic systems containing medium-sized rings from carbohydrates.[8] As an extension of this work, we recently described a concise formal synthesis[9] of guanacastepene A, an antibacterial diterpenoid natural product with a novel carbon skeleton.[10,11] Our approach was based on the simultaneous construction of the seven- and six-membered rings through a tandem RCM reaction i.e., **6** → **7** (Scheme 1). Among the issues that had to be addressed to achieve the synthesis of guanacastepene A was the elaboration of the tricyclic core with the quaternary carbon center at C8 (guanacastepene numbering) bearing conveniently

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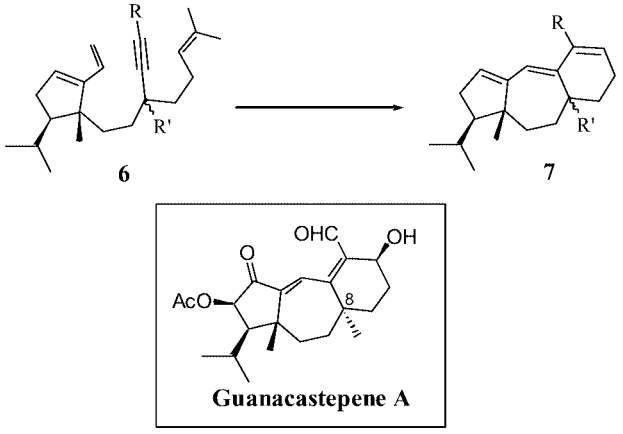
positioned oxygen functionalities. To this end, various dienynes **6a**–**g** (R = CO_2Me, H, Me, TMS; R′ = OTES, H, Me) were prepared and submitted to the RCM reactions. This paper describes our observations on the influence of substrate substitution, in particular the ester group and the quaternary propargylic center, on the tandem cyclization.

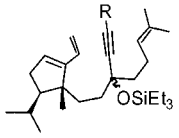
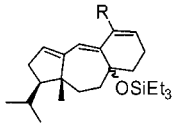
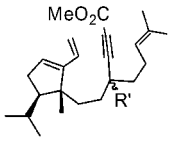
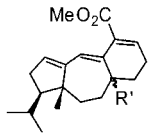


Scheme 1.

Results and Discussion

The reactivity of dienyne **6a**[12] in the presence of catalysts **2** and **3** was first examined. In all attempts, catalyst **2** was found to be ineffective and the starting dienyne was recovered unchanged. Treating **6a** with 10 mol-% of the second-generation Grubbs catalyst **3** in CH_2Cl_2 at reflux led to the disappearance of the starting material and the formation of an intractable mixture of products. However, when this reaction was carried out at room temperature, the desired product **7a** was produced in 40–60% yield. The instability of this product[13] led us to investigate whether this factor was responsible for this modest yield. After considerable experimentation, we found that by simply stirring the solution of **6a** and catalyst **3** (7.5 mol-%) in CH_2Cl_2 at room temperature under a stream of nitrogen overnight, such that the solvent slowly evaporated, the reaction was completed and tricyclic triene **7a** was obtained in 78–81% yield. As can be seen from the results compiled in Table 1, the interposing alkyne tolerates methyl substitution (entry 2). In contrast, the hindered trimethylsilyl substituent directly attached to the alkyne impedes the diene-initiated RCM (entry 3). In this case the starting dienyne **6c** remained unchanged.[14] Recourse to higher temperature (reflux in CH_2Cl_2 or benzene), more catalyst, and longer reaction times resulted in partial conversion of the starting dienyne and formation of inseparable mixture. The ester-substituted dienyne **6d** requires more forcing conditions but succeeds in delivering the tricyclic product **7d** in excellent reproducible yield (entry 4). In this case, the tandem process must pass through a quite unstable enoic carbene complex, which undergoes diene metathesis to produce **7d**.[15] In contrast to **7a**,**b**, triene **7d** is sufficiently stable to be isolated by chromatography on silica gel. Similarly, triene **6e**, in which the triethylsilyloxy group has been replaced by a methyl group (entry 5), undergoes a tandem RCM to provide triene **7e** in good yield. The reaction of dienyne **6f**, which contains a tertiary propargylic center, needed a longer time to reach completion and gave **7f** in 78% yield (entry 6).

Table 1. Tandem RCM of dienynes **6a**–**6f**.[a]

Entry	Dienyne	% Catalyst	*t* °C (time, h)	Product	(Yield)
					
1	**6a** R = H	7.5%	r.t. (17)	**7a** R = H	(81%)
2	**6b** R = Me	7.5%	r.t. (17)	**7b** R = Me	(70%)
3	**6c** R = TMS		r.t. (17)	**7c** R = TMS	nr
4	**6d** R = COOMe	5%	reflux (4)	**7d** R = COOMe	(93%)
					
5	**6e** R′ = Me	10%	reflux (3)	**7e** (R′ = Me)	(82%)
6	**6f** R′ = H	10%	reflux (17)	**7f** (R′ = H)	(78%)

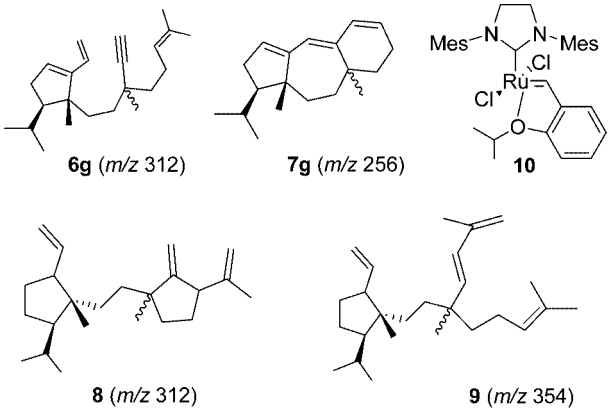
[a] Reactions carried out in the presence of $(4–9)\times10^{-2}$ M catalyst **3** in CH_2Cl_2.

Unexpectedly, under similar reaction conditions (10 mol-% catalyst **3**, CH_2Cl_2 at reflux for 12 h) dienyne **6g**, which lacks the ester group, furnished a mixture of products. The main fraction, isolated by chromatography on silica gel, was found to be a mixture of the metathesis product **7g** and the cycloisomerization product **8** (1:2 ratio) in 45% combined yield. Besides **7g** and **8**, a minor product **9** was isolated (11%) along with unchanged starting material (Table 2).

When the Hoveyda–Grubbs catalyst **10**[16] (10 mol-%) was used, further cycloisomerization occurred and a mixture of **7g** and **8** was isolated in a 1:4 ratio. This result suggests that the alkyne is more reactive toward the ruthenium–carbene complex than the terminal alkene for dienyne **6g**. Therefore, initial coordination preferentially occurs at the alkyne to give the metallacyclopentene **D** (path b) rather than at the double bond to give metallacyclobutane complex **C** (path a; Figure 2).[17]

Although a variety of ruthenium compounds are known to catalyze the cycloisomerization of enynes,[17a] to the best of our knowledge such a behavior has never been seen in the RCM reactions before. In order to confirm the structure of **8**, dienyne **6g** was submitted to Alder ene reaction conditions. When **6g** was treated with bis(triphenylphosphane)-palladium acetate $[(PPh_3)_2Pd(OAc)_2]$ (**11**)[18] in toluene at room temperature overnight, compound **8** was isolated as the sole rearranged product as a mixture of diastereoiso-

Table 2. RCM and cycloisomerization of dienyne **6g**.



Entry	Catalyst	Products (yield)		
1	**3**[a]	**7g** + **8** (1:2)[b]	**9** (11%)	**6g** (6.5%)
2	**10**[a]	**7g** + **8** (1:4)[b]	(45%)	**6g** (6.5%)
3	**11**[c]	**8** (25%)	(41%)	**6g** (25%)

[a] Reactions in refluxing CH_2Cl_2 (10^{-2} M) for 12 h. [b] Determined by ^1H NMR spectroscopy. [c] Reaction in toluene at room temp.

mers along with the recovered starting dienyne (entry 3). The spectroscopic data of this product are identical to those obtained under metathesis conditions. Structure **8** was assigned on the basis of IR, MS, ^1H and ^{13}C NMR spectroscopic analysis. In particular, the mass spectrum established that **6g** and **8** are isomeric compounds (*m*/*z* = 312), the IR spectrum shows the disappearance of the CH alkyne absorption, and the ^{13}C NMR spectrum exhibits eight signals of sp^2 carbons: three CH_2 at δ = 104.6, 112.3, and 113.5 ppm, two CH at δ = 126.2 and 132.0 ppm, and three quaternary carbons at δ = 146.8, 149.2, and 161.8 ppm.

Although the reason for this striking difference between the reactivity of **6g** and **6a** is still unclear, the easy cyclization of dienyne **6a** may be the result of a Thorpe–Ingold effect of the triethylsilyloxy group. Presumably, replacing OTES by methyl gives rise to an unfavorable conformation that inhibits the reaction of the ruthenium–carbene complex with the terminal double bond. More intriguing is the heightened tendency for the tandem metathesis process shown by dienyne **6e** in comparison to its terminal alkyne counterpart **6g**, although it is known that in some cases coordination of the evolving Ru–carbene to the ester group may slow-down or completely impede the cyclization.[19]

This unexpected result prompted us to study the influence of the substrate substitution on the metathetic reactivity of dienynes in more detail. To probe the effects of the pre-existing cyclopentene ring and the ester group, acyclic dienynes **12a** and **12b** were prepared and subjected to the metathesis conditions (Table 3). The synthesis of these compounds was achieved starting from known nitrile **13**.[20] Setting up the quaternary center was accomplished by alkylation of **13** with 6-bromo-1-hexene in the presence of lithium hexamethyldisilazide at room temperature. The resulting nitrile **14** was reduced to aldehyde **15**, which was subjected to the action of dimethyl 1-diazo-2-oxopropylphosphonate (the Ohira reagent)[21] in the presence of K_2CO_3 in MeOH to give the acetylenic derivative **12a**. Conversion of **12a** into **12b** was effected in the usual way (Scheme 2).

When a dichloromethane solution of dienyne **12b** and 5% of **3** was heated at reflux temperature for 3 h, the metathesis product **16b** was isolated in 76% yield. Under the same conditions, dienyne **12a**, which lacks the ester group, furnished a mixture of the expected bicyclic diene **16a** and the 12-membered ring dimeric product **17** (1:2 ratio) in 90% combined yield.[22] The structure of **17** was assigned on the basis of its spectroscopic data. In particular, the ^1H NMR

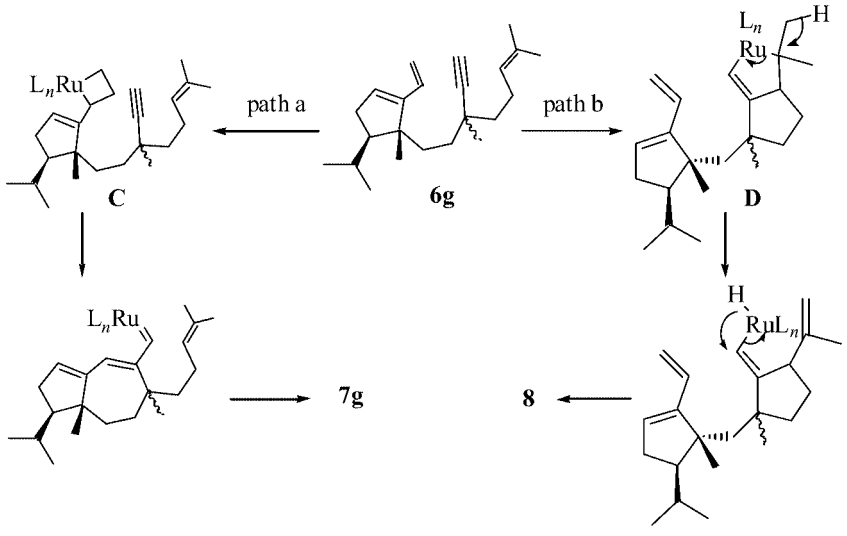
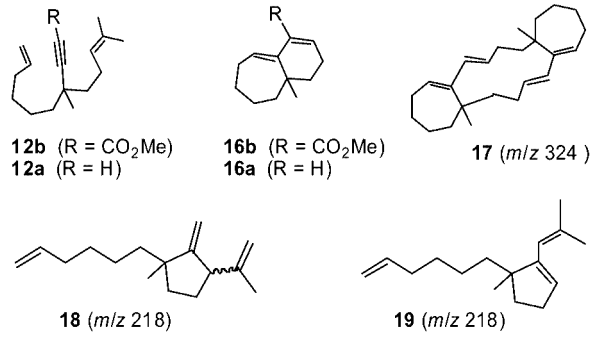


Figure 2. Metathesis and cycloisomerization pathways of dienyne **6g**.

Table 3. RCM and cycloisomerization of dienynes **12a** and **12b**.



Entry	Substrate	Catalyst, concentration	Product (yield)
1[a]	**12b**	**3** (5%) $2\cdot10^{-2}$ M	**16b** (76%)
2[a]	**12a**	**3** (5%) $2\cdot10^{-2}$ M	**16a** (30%) + **17** (60%)
3[a]	**12a**	**3** (5%) $5\cdot10^{-3}$ M	**16a** (60%) + **17** (30%)
4[a]	**12a**	**3** (5%) 10^{-3} M	**16a** (86%)
5[b]	**12a**	**11**	**18** (33%) + **12a** (22%)
6[b]	**12a**	$PtCl_2$	**19** (88%)

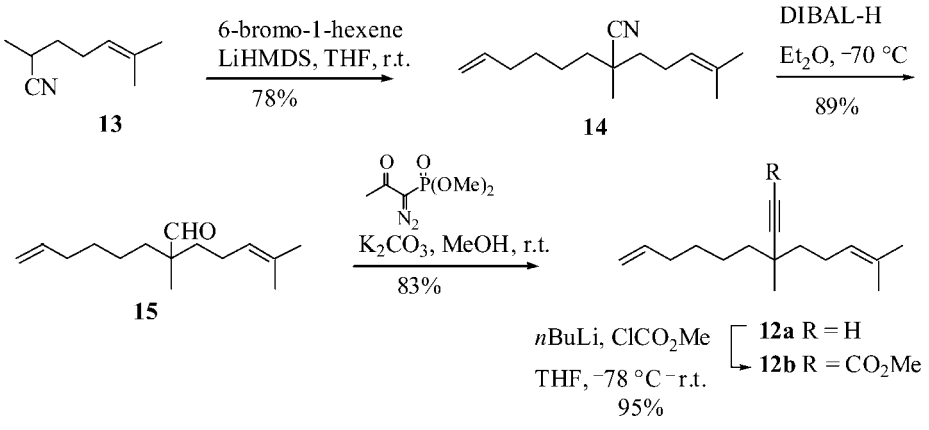
[a] Reactions in refluxing CH_2Cl_2 for 3 h. [b] In toluene at 60 °C.

spectrum does not show any signals for terminal double bonds and the ^{13}C NMR spectrum contains resonances for six secondary sp^2 carbons. The ratio of **16a** to **17** was reversed when the reaction was carried out under more dilute conditions (entry 3). At 10^{-3} M concentration, only the tandem metathesis product **16a** was obtained in 86% yield. In contrast to dienyne **6g**, no cycloisomerization product such as **18** was isolated.

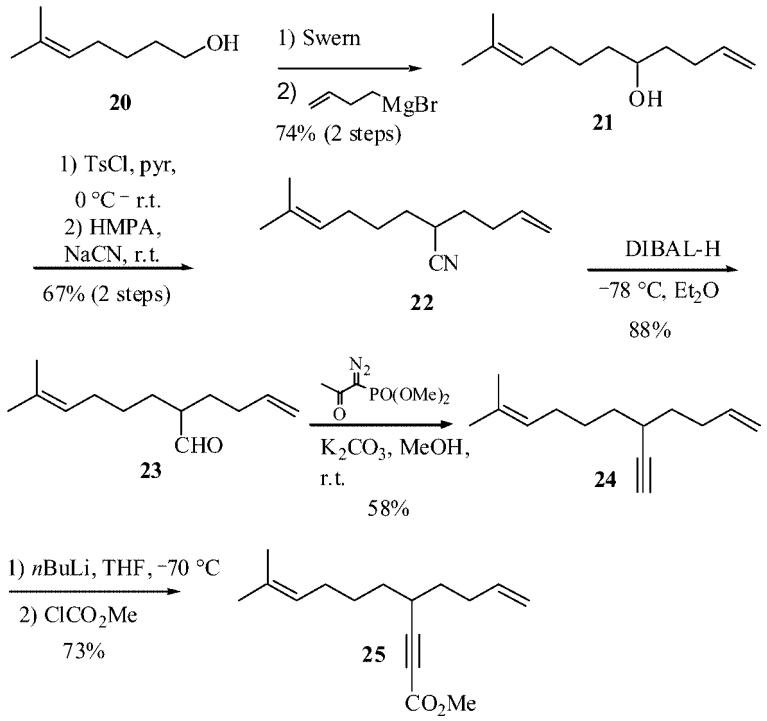
This result confirms the favorable effect of the ester group on the tandem process. It also suggests that the unusual behavior of **6g** toward the metathesis catalysts could be due to the pre-existing cyclopentene ring. As for **6g**, when dienyne **12a** was treated with palladium-based catalyst **11**, only compound **18** was obtained. On the other hand, treatment of **12a** with a catalytic amount of $PtCl_2$ in toluene at 60 °C furnished **19** in good yield (entry 6).[23] These results are in agreement with the well known behavior of 1,6-dienynes: the coordination of palladium or platinum catalysts occurs at the alkyne part, leading to cycloisomerization products. [24]

To assess the effect of the quaternary center linked to the alkyne, various acyclic dienynes were prepared (Schemes 3 and 4) and subjected to metathesis conditions. The results shown in Table 4 are instructive in different ways. When dienyne **35**, which bears two monosubstituted alkene moieties, was treated with the first-generation Grubbs catalyst **2** (entry 1), two bicyclic compounds **40** and **41** were isolated in equal amounts. The 1:1 product ratio arises from the unselective initial acyclic metathesis. Under the same conditions, its counterpart **24** led only to the initial enyne RCM product **42**, which can be transformed into **40** by treatment with catalyst **3** at reflux temperature. Treatment of **24** with catalyst **3** in refluxing CH_2Cl_2 for 4 h gave the biyclic compound **40** (59%). The ester-substituted dienyne **25** did not afford any bicyclic compound, and the product of the initial enyne metathesis **43** was isolated in 28% yield along with the completely unexpected product **44** (entry 6). This structure, which was assigned after careful analysis of spectroscopic data, is the result of the Diels–Alder dimerization reaction of **43**. The high tendency of dienyne **25** to dimerize after the initial enyne RCM may be explained by a possible coordination of the Ru–carbene to the ester, which completely impedes the second cyclization.[19] Comparison of these results with those of Table 1 (entries 4 and 5) underlines the favorable effect of both the pre-existing cyclopentene ring and the quaternary centers on the cyclization.

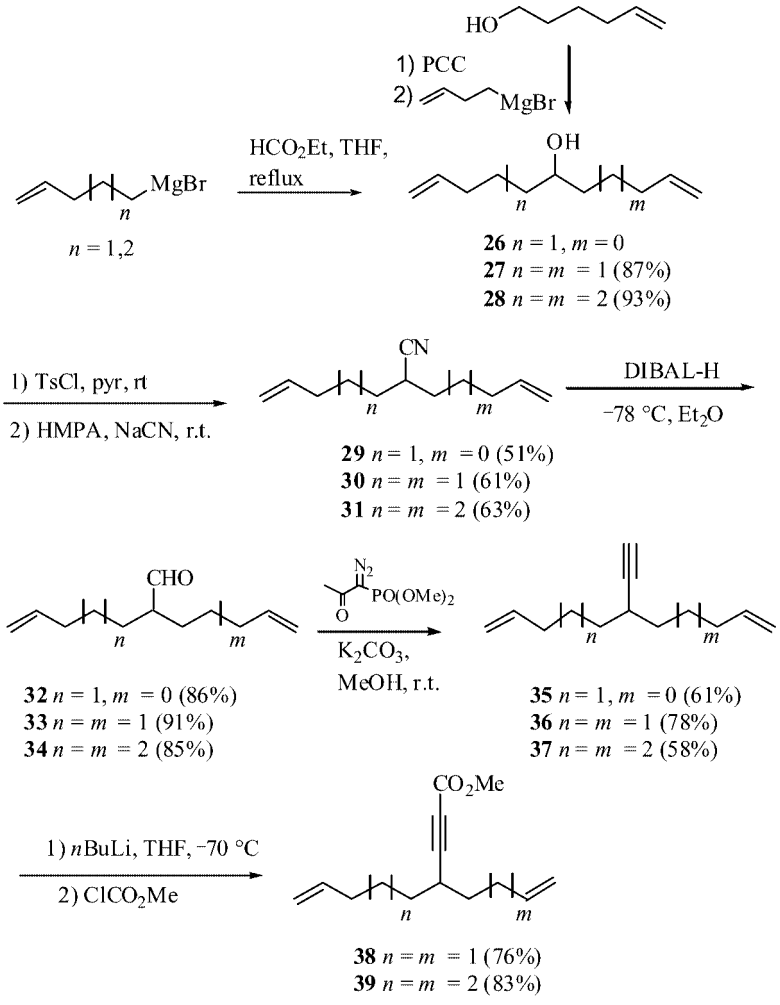
Whereas dienyne **36**, which possesses symmetrically tethered alkenes, undergoes the tandem process with catalyst **3** easily and selectively to furnish the [5.4.0]bicyclic derivative **45** in quantitative yield, its ester-substituted counterpart **38**



Scheme 2.

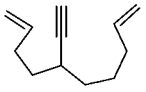
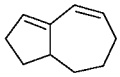
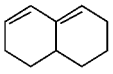
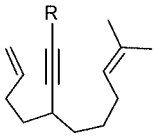
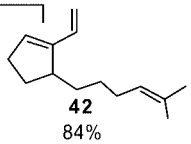
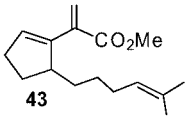
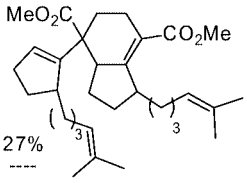
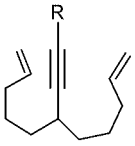
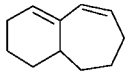
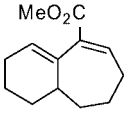
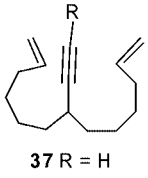
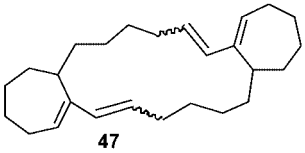
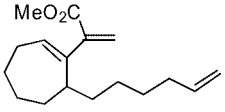


Scheme 3.



Scheme 4.

Table 4. Tandem RCM of acyclic dienynes.[a]

Entry	Dienyne	Ru catalyst, temp.	Metathesis products
1	 **35**	**2** (8.5%), 20 °C	 **40** 47%  **41** 47%
2		**3** (8.5%), 20 °C	51% 42%
3		**3** (8.5%), reflux	45% 45%
4	 **24** R = H	**2** (8.5%), 20 °C	----  **42** 84%
5		**3** (7.5%), reflux, 4h	**40** 59% ----
			3 (8%), reflux, 4 h, 64%
	25 R = CO_2Me		 **43**  **44**
6		**2** (10%)	28% 27%
7		**3** (10%), reflux, 4 h	73% ----
8	 **36** R = H	**2** (8.5%), 20 °C	 **45** 100%
	38 R = CO_2Me		 **46**
9		**2** (10%), reflux, 3 h	-----
10		**3** (10%), reflux, 3 h	34%
11	 **37** R = H	**3** (10%) 0.04 M (reflux, 3 h)	 **47** 32%
12		**3** (10%) 0.01 M	51%
	39 R = CO_2Me		 **48**
13		**2** (10%)	(trace)
14		**3** (10%) reflux, 3 h	71%

[a] Reactions carried out at $(1–4)\times10^{-2}$ M in CH_2Cl_2.

failed to give any tandem cyclization product. However, when treated with catalyst **3** in refluxing CH_2Cl_2, **38** led to a mixture of the expected bicyclic diene **46** in low yield (34%; entry 10).

The RCM reaction of dienynes possessing longer alkene chains was next attempted. Treatment of **37** with catalyst **3** in refluxing CH_2Cl_2 led to a mixture of products from which one major compound was isolated as a white solid in 51% yield (entry 12). Its mass, ^1H, and ^{13}C NMR spectra are in agreement with the macrocyclic structure **47**. In this case, the initial enyne RCM is followed by dimerization and the resulting α,ω-diene undergoes cyclization to give **47**. The same product was obtained with a higher yield when the reaction was carried out in more dilute solution. As for **20**, the ester-substituted dienyne **39** affords only the product of the initial enyne metathesis **48** in 71% yield. This result

is in agreement with the much higher cyclization rate of the seven-membered ring over that of the eight-membered ring. The lack of conformational constraints in these substrates does not facilitate the assembly of the cyclooctyl moiety.[25]

Conclusions

The examples presented here show the effect of substrate substitution and tether length on the RCM reaction of dienynes. The tandem-RCM of dienynes having quaternary centers attached to the alkyne and a pre-existing cycle proceeds smoothly to afford tricyclic compounds in high yields. For these substrates, a high selectivity for ring sizes has been achieved by modifying the reactivity of one alkene with steric factors. However, in one case (dienyne **6g**) an unprecedented non-metathetic activity of second-generation catalysts **3** and **10** was observed. In this case, the cycloisomerization product was obtained as the major product. In the absence of favorable factors, especially when the starting substrates contain hindered alkenes, a long tether chain, and/or ester group on the alkyne part, the tandem process was slowed down or completely impeded. In these cases, the dienynes behave like simple enynes to afford initial metathesis products; further reactions would proceed to give dimeric compounds, the cross-metathesis, or the intermolecular Diels–Alder products.

Experimental Section

General: Infrared spectra were recorded with neat substances or solutions in CCl_4. ^1H and ^{13}C NMR spectra were recorded with a 300 or 400 MHz instrument as solutions in $CDCl_3$, using residual protic solvent $CHCl_3$ (δ_H = 7.27 ppm) or $CDCl_3$ (δ_C = 77.0 ppm) as internal reference. Mass spectra were obtained either by electronic impact (EI) or chemical ionization with ammonia (CI, NH_3). All reactions were monitored by TLC carried out on 0.2-mm aluminum silica gel (60 F_{254}) pre-coated plates using UV light and 5% ethanolic phosphomolybdic acid and heat as developing agent. Flash chromatography was performed on 40–63-μm (400–230 mesh) silica gel 60 with ethyl acetate (EtOAc)/petroleum ether (PE; boiling range 40–60 °C) or cyclohexane as eluents. Commercially available reagents and solvents were purified and dried where necessary by usual methods. THF, benzene, and Et_2O were purified by distillation under nitrogen from sodium/benzophenone. CH_2Cl_2, HMPA, and MeOH were dried by distillation from calcium hydride under argon.

General Procedure for the Metathesis Reaction of Dienynes 6a and 6b. Synthesis of Tricyclic Triene 7a: Catalyst **3** (11 mg, 7.5 mol-%) was added to a degassed solution of dienyne **6a** (75 mg, 0.175 mmol) in dry dichloromethane (2 mL). The mixture was then stirred at room temperature overnight under a stream of nitrogen such that the solvent slowly evaporated. The resulting residue was purified by rapid chromatography on Florisil (eluting with pure petroleum ether) to give compound **7a** as a 1:1 mixture of two isomers (53 mg, 81%). Colorless oil. ^1H NMR: δ = 5.98 (dd, J = 9.6, 2.4 Hz, 1 H), 5.89 (d, J = 5.8 Hz, 1 H), 5.80–5.65 (m, 1 H), 5.56 (br. s, 0.5 H), 5.49 (br. s, 0.5 H), 2.45–2.32 (m, 2 H), 2.10–1.90 (m, 3 H), 1.82–1.58 (m, 7 H), 1.73 (s, 3 H), 1.60 (s, 3 H), 1.03 (d, J = 5.6 Hz, 3/2 H), 1.01 (s, 3/2 H), 0.99–0.87 (1 s + 2 t + 3 d, 15 H), 0.65 (q, J = 7.9 Hz, 6/2 H), 0.55 (q, J = 7.9 Hz, 6/2 H) ppm. ^{13}C NMR: δ = 150.5 (C), 139.5 (C), 130.6 (CH), 128.84 (CH), 128.75 (CH), 127.9 (CH), 127.4 (CH), 123.7 (CH), 75.7 (C), 58.0 (CH), 51.8 (C), 38.76 (CH_2), 38.67 (CH_2), 37.5 (CH_2), 36.0 (CH_2), 34.3 (CH_2), 29.5 (CH), 25.7 (CH_3), 23.12 (CH_3), 23.04 (CH_3+CH_2), 22.7 (CH_3), 22.5 (CH_3), 7.4 (CH_3), 6.9 (CH_3+CH_2), 6.4 (CH_2) ppm. IR (CCl_4): $\tilde{\nu}$ = 3025, 2955, 2874, 2829, 1618, 1457, 1081 cm^{-1}. HRMS (EI): m/z calcd. for $C_{24}H_{40}OSi$ 372.28485; found 372.28511.

Tricyclic Compound 7b: Prepared from dienyne **6b** (39 mg, 0.088 mmol) by the same procedure as for **7a** (24 mg, 70%). Colorless oil, two isomers (1:1). ^1H NMR: δ = 6.08 (s, 0.5 H), 6.04 (s, 0.5 H), 5.66 (br. s, 0.5 H), 5.58 (br. s, 0.5 H)), 5.52 (br. s, 0.5 H), 5.46 (br. s, 0.5 H), 2.52–2.25 (m, 3 H), 2.10–1.52 (m, 9 H), 1.89 (s, 3 H), 1.04–0.86 (2 s + 2 t + 4 d, 18 H), 0.61 (q, J = 7.5 Hz, 3 H), 0.51 (q, J = 7.7 Hz, 3 H) ppm. ^{13}C NMR: δ = 150.7 (C), 141.8 (C), 132.4 (C), 127.9 (CH), 127.6 (CH), 126.1 (CH), 119.8 (CH), 77.2 (C), 57.1 (CH), 52.1 (C), 39.2 (CH_2), 38.2 (CH_2), 37.7 (CH_2), 36.3 (CH_2), 35.9 (CH_2), 33.2 (CH_2), 29.7 (CH), 29.6 (CH), 23.5 (CH_2), 23.2 (CH_3), 23.0 (CH_3), 22.8 (CH_3), 21.0 (CH_3), 7.4 (CH_3), 7.3 (CH_3), 6.8 (CH_2), 6.2 (CH_2) ppm. HRMS (EI): m/z calcd. for $C_{25}H_{42}OSi$ 386.30050; found 386.30005.

Typical Procedure for the Metathesis Reaction of 6d–6g. Synthesis of Tricyclic Compound 7d: Catalyst **3** (18 mg, 10 mol-%) was added to a degassed solution of dienyne **6d** (105 mg, 0.216 mmol) in dry dichloromethane (3 mL) under nitrogen. The mixture was heated at reflux for 4 h. The solvent was removed and the residue was purified by flash chromatography (ethyl acetate/petroleum ether, 2.5:97.5) to give **7d** (86 mg, 93%) as a colorless oil. Two isomers (55:45). ^1H NMR: δ = 6.74 (t, J = 3.9 Hz, 0.55 H), 6.57 (br. s, 0.55 H), 6.51 (br. s, 0.45 H), 6.25 (s, 0.45 H), 5.57 (br. s, 0.55 H), 5.44 (br. s, 0.45 H), 3.75 (s, 1.65 H), 3.73 (s, 1.35 H), 2.51–2.30 (m, 3 H), 2.21–2.11 (m, 2 H), 2.05–1.50 (m, 7 H), 1.04–0.84 (1 s + 2 t + 3 d, 18 H), 0.58 (q, J = 7.7 Hz, 6/2 H), 0.52 (q, J = 7.7 Hz, 6/2 H) ppm. ^{13}C NMR: δ = 168.1 (C), 168.0 (C), 150.0 (C), 149.6 (C), 138.6 (CH), 137.4 (br. C), 135.5 (C), 131.9 (C), 128.9 (CH), 124.1 (CH), 75.8 (C), 58.0 (CH), 56.5 (CH), 55.3 (C), 52.0 (C), 51.6 (CH_3), 38.2 (CH_2), 37.5 (CH_2), 37.1 (CH_2), 36.4 (CH_2), 35.9 (CH_2), 32.7 (CH_2), 32.6 (CH_2), 29.7 (CH), 29.4 (CH), 24.2 (CH_2), 23.2 (CH_2), 23.0 (CH_3), 22.9 (CH_3), 21.1 (CH_3), 7.3 (CH_3), 7.2 (CH_3), 6.7 (CH_2), 6.2 (CH_2) ppm. IR (CCl_4): $\tilde{\nu}$ = 2954, 2874, 1720, 1456, 1254, 1077 cm^{-1}. HRMS (EI): m/z calcd. for $C_{26}H_{42}O_3Si$ 430.29033; found 430.29011.

Tricyclic Triene 7e: Yield: 514 mg (82%). Colorless oil, two isomers. ^1H NMR: δ = 6.53 (br. s, 0.5 H), 6.25 (br. s, 0.5 H), 6.20 (br. s, 1 H), 5.55 (br. s, 0.5 H), 5.46 (br. s, 0.5 H), 3.76 (s, 1.5 H), 3.74 (s, 1.5 H), 2.45–2.15 (m, 3 H), 2.10–1.55 (m, 6 H), 1.50–1.10 (m, 3 H), 1.04–0.84 (2 s + 2 d, 12 H) ppm. ^{13}C NMR (key signals): δ = 169.1 (C), 150.9 (C), 137.8 (C), 135.6 (CH), 135.4 (CH), 133.3 (C), 132.0 (br), 129.6 (CH), 129.4 (CH), 124.5 (CH), 124.4 (CH), 59.0 (CH), 51.6 (CH_3) ppm. IR (CCl_4): $\tilde{\nu}$ = 1722, 1618 cm^{-1}. CI MS (NH_3): m/z = 315 [M^+ + 1], 332 [M^+ + 18]. HRMS (EI): m/z calcd. for $C_{21}H_{30}O_2$, 314.22458; found 314.22302.

Tricyclic Triene 7f: Yield: 18 mg (78%) Colorless oil. Two isomers. ^1H NMR: δ = 6.49 (t, J = 4.5 Hz, 0.5 H), 6.43 (br. s, 0.5 H), 6.38 (t, J = 4.5 Hz, 0.5 H), 6.33 (br. s, 1 H), 5.57 (br. s, 0.5 H), 5.51 (br. s, 0.5 H), 3.78 (s, 1.5 H), 3.76 (s, 1.5 H), 2.45–2.15 (m, 4 H), 2.10–1.10 (m, 6 H), 1.50–2.10 (m, 3 H), 1.00–0.90 (2 s + 2 d, 12 H) ppm. ^{13}C NMR (key signals): δ = 170.0 (C), 169.0 (C), 151.6 (C), 150.3 (C), 136.3 (C), 136.0 (CH), 135.0 (C), 134.6 (C), 133.3 (C), 134.5 (CH), 133.3 (C), 131.2 (CH), 129.7 (CH), 128.6 (C), 128.0 (C), 125.0 (CH), 124.7 (CH), 58.9 (CH), 58.3 (CH), 52.5 (C), 51.9 (CH_3), 51.8 (CH_3), 49.7 (C), 42.8 (CH), 41.6 (CH), 41.1 (CH_2),

40.2 (CH_2), 36.4 (CH_2), 35.9 (CH_2), 32.8 (CH_2), 32.1 (CH_2), 31.1 (CH_2), 30.2 (CH_2), 29.6 (CH), 29.5 (CH), 26.3 (CH_2), 25.8 (CH_2), 23.5 (CH_3), 23.2 (CH_3), 23.11 (CH_3), 23.08 (CH_3), 22.8 (CH_3), 18.7 (CH_3) ppm. IR (CCl_4): $\tilde{\nu}$ = 1722, 1615 cm^{-1}. CI MS (NH_3): *m*/*z* = 301 [M^+ + 1], 196.

Metathesis of 6g: Treatment of **6g** (12 mg, 0.038 mmol) with catalyst **3** (10 mol-%) in refluxing CH_2Cl_2 for 12 h afforded 5 mg of an inseparable mixture of **7g**, **8** and 1 mg of **9** in 58% combined yield. **Tricyclic Triene 7g:** Colorless oil. Two isomers. ^{1}H NMR: δ = 5.97 (d, *J* = 10 Hz, 1 H), 5.87 (d, *J* = 6.8 Hz, 1 H), 5.75–5.70 (m, 1 H), 5.50 (br. s, 0.5 H)), 5.47 (br. s, 0.5 H), 2.45–2.15 (m, 3 H), 2.10–1.55 (m, 6 H), 1.50–2.10 (m, 3 H), 1.08–0.91 (2 s + 2 d, 12 H) ppm. CI MS (NH_3): *m*/*z* = 257 [M^+ + 1], 294 [M^+ + 18].

Alder Ene Product 8: Colorless oil. Major isomer. ^{1}H NMR (key signals): δ = 6.21–6.12 (m, 1 H), 5.75 (br. s, 1 H), 5.42 (br. d, *J* = 18 Hz, 1 H), 5.02 (br. d, *J* = 11 Hz, 1 H), 4.86–4.95 (m, 4 H), 3.20–3.17 (m, 1 H), 2.40–2.25 (m, 2 H), 2.10–1.10 (m, 10 H), 1.63 (s, 3 H), 1.90–1.63 (m, 12 H) ppm. ^{13}C NMR (key signals): δ = 161.8 (C), 149.2 (C), 146.8 (C), 132.0 (CH), 126.3 (CH), 113.5 (CH_2), 112.4 (CH_2), 104.6 (CH_2) ppm. CI MS (NH_3): *m*/*z* = 313 [M^+ + 1], 330 [M^+ + 18]. HRMS (EI): *m*/*z* calcd. for $C_{23}H_{36}$ 312.28170; found 312.28308.

Compound 9: Colorless oil, two isomers. ^{1}H NMR: δ = 6.15–6.05 (m, 1 H), 6.02 (d, *J* = 16 Hz, 1 H), 5.73 (br. s, 1 H), 5.50 (d, *J* = 16 Hz, 1 H), 5.37 (d, *J* = 17 Hz, 1 H), 5.15–5.04 (m, 1 H), 4.97 (d, *J* = 10 Hz, 1 H), 4.89 (s, 1 H), 4.88 (s, 1 H), 2.35–2.29 (m, 1 H), 2.10–1.90 (m, 1 H), 1.83 (s, 3 H), 1.67 (s, 3 H), 1.57 (s, 3 H), 1.90–1.00 (m, 10 H), 0.98 (s, 3 H), 0.96 (s+d, 6 H), 0.89 (d, *J* = 6.4 Hz, 3 H) ppm. ^{13}C NMR: δ = 149.2 (C), 142.41 (C), 142.38 (C), 139.80 (CH), 139.74 (CH), 132.0 (CH), 130.9 (C), 129.8 (CH), 129.7 (CH), 126.25 (CH), 126.23 (CH), 125.2 (2CH), 114.05 (CH_2), 114.02 (CH_2), 113.5 (CH_2), 50.7 (CH), 50.04 (C), 49.95 (C), 41.6 (CH_2), 41.1 (CH_2), 38.8 (C), 38.7 (C), 36.2 (CH_2), 36.0 (CH_2), 35.12 (CH_2), 35.08 (CH_2), 32.23 (CH_2), 32.21 (CH_2), 29.3 (CH), 25.6 (CH_3), 23.3 (CH_3), 23.0 (CH_2), 22.98 (CH_2), 22.9 (CH_3), 22.74 (CH_3), 22.70 (CH_3), 22.59 (CH_3), 22.51 (CH_3), 20.88 (CH_3), 20.84 (CH_3), 18.7 (CH_3), 17.6 (CH_3) ppm. CI MS (NH_3): *m*/*z* = 355 [M^+ + 1], 372 [M^+ + 18]. HRMS (EI): *m*/*z* calcd. for $C_{26}H_{42}$ 354.32865; found 354.32764.

Cycloisomerization of 6g. Alder Ene product 8: [$Pd(OAc)_2(PPh_3)_2$] (2 mg) was added to a degassed solution of **6g** (8 mg, 0.02 mmol) in dry toluene (0.2 mL) under nitrogen. The mixture was stirred at room temp. for 24 h, then the solvent was evaporated under vacuum. Purification by flash chromatography (PE) afforded 2 mg of **8** (25%) followed by 2 mg of **6g** (25%).

Synthesis of Compounds 12

Nitrile 14: A solution of LiHMDS (8 mL, 1.0 M in THF) was added dropwise, at room temp., to a solution of **13** (548 mg, 4 mmol) and 6-bromo-1-hexene (1.30 g, 8 mmol) in dry THF (7 mL). After being stirred at this temperature for 1 h (TLC showed disappearance of the starting material), the mixture was cooled to 0 °C and quenched with water. The two phases were separated and the aqueous phase was extracted with three 20-mL portions of Et_2O. The combined organic phases were washed with brine, dried with $MgSO_4$, and concentrated. The crude product was purified by flash chromatography on silica gel (2.5% EtOAc in PE) to give 688 mg of **14** (78%) as a colorless oil. R_f = 0.60 (2.5% EtOAc in PE). ^{1}H NMR: δ = 5.90–5.70 (m, 1 H), 5.08 (t, *J* = 7.2 Hz, 1 H), 5.00 (d, *J* = 17.6 Hz, 1 H), 4.96 (d, *J* = 10 Hz, 1 H), 2.10–2.00 (m, 4 H), 1.68 (s, 3 H), 1.62 (s, 3 H), 1.52–1.35 (m, 8 H), 1.30 (s, 3 H) ppm. ^{13}C NMR: δ = 138.4 (CH), 132.7 (C), 124.5 (C), 122.7 (CH), 114.8 (CH_2), 39.3 ($2CH_2$), 36.5 (C), 33.5 (CH_2), 28.9 (CH_2) 25.7 (CH_3), 24.3 (CH_2), 24.0 (CH_3), 23.6 (CH_2), 17.7 (CH_3) ppm. IR (CCl_4): $\tilde{\nu}$ = 3078, 2232, 1641 cm^{-1}. HRMS (EI): *m*/*z* calcd. for $C_{15}H_{25}N$ 219.19870; found 219.19917.

Aldehyde 15: A solution of DIBAL-H 1.0 M in hexane (2.4 mL) was added dropwise to a solution of nitrile **14** (257 mg, 1.17 mmol) in dry Et_2O (3 mL) cooled to –70 °C and stirred under nitrogen. After being stirred at this temperature for 30 min, EtOAc was added and the mixture was slowly warmed up to room temp. A solution of potassium sodium tartrate (Rochelle salt) was added and the mixture was stirred for 30 min until the layers appeared clear. The phases were separated and the aqueous layer was extracted three times with Et_2O. The combined organic phases were washed with brine, dried with $MgSO_4$, and concentrated to give crude **15**. Flash chromatography on silica gel (1.25% EtOAc in PE) gave 216 mg of **15** (89%) as a colorless liquid. R_f = 0.30 (pentane). ^{1}H NMR: δ = 9.46 (s, 1 H), 5.83–5.75 (m, 1 H), 5.10 (t, *J* = 5.2 Hz, 1 H), 5.03 (dd, *J* = 12.6, 1.2 Hz, 1 H), 4.98 (d, *J* = 7.8 Hz, 1 H), 2.08 (q, *J* = 7.9 Hz, 2 H), 2.00–1.82 (m, 2 H), 1.71 (s, 3 H), 1.62 (s, 3 H), 1.60–1.40 (m, 6 H), 1.16–1.08 (m, 2 H), 1.07 (s, 3 H) ppm. ^{13}C NMR: δ = 206.6 (C), 138.7 (CH), 132.2 (C), 123.9 (CH), 114.6 (CH_2), 49.1 (C), 35.7 (CH_2), 35.3 (CH_2), 33.6 (CH_2), 29.5 (CH_2), 25.7 (CH_3), 25.4 (CH_2), 22.8 (CH_2), 18.1 (CH_3), 17.7 (CH_3) ppm. IR (CCl_4): $\tilde{\nu}$ = 1724, 1641 cm^{-1}. HRMS (EI): *m*/*z* calcd. for $C_{15}H_{26}O$ 222.19837; found 222.19943.

Dienyne 12a: K_2CO_3 (640 mg, 4.62 mmol) was added to a solution of aldehyde **15** (423 mg, 1.90 mmol) and dimethyl 1-diazo-2-oxopropylphosphonate[21] (760 mg, 2.71 mmol) in anhydrous MeOH (34 mL) and stirring was continued under argon for 3 h. The reaction mixture was diluted with Et_2O (20 mL), washed with an aqueous solution of $NaHCO_3$ (10%) and brine, and dried ($MgSO_4$). Evaporation of the solvents followed by flash chromatography on silica gel (pentane) gave 340 mg of 1-alkyne **12a** (1.55 mmol, 83%) as a colorless liquid. R_f = 0.90 (pentane). ^{1}H NMR: δ = 5.88–5.75 (m, 1 H), 5.14–5.09 (m, 1 H), 5.05–4.93 (m, 2 H), 2.35–2.29 (m, 1 H), 2.12–2.05 (m, 5 H), 1.69 (s, 3 H), 1.63 (s, 3 H), 1.50–1.17 (m, 8 H), 1.18 (s, 3 H) ppm. ^{13}C NMR: δ = 138.6 (CH), 131.4 (C), 124.3 (CH), 114.5 (CH_2), 90.6 (C), 68.9 (CH), 41.4 (CH_2), 40.9 (CH_2), 34.7 (C), 34.1 (CH_2), 26.3 (2 CH_2), 25.6 (CH_2), 24.0 (CH_3), 23.5 (CH_3), 17.5 (CH_3) ppm. IR (neat): $\tilde{\nu}$ = 3309, 1641 cm^{-1}. CI MS (NH_3): *m*/*z* = 219 [M^+ + 1], 236 [M^+ + 18]. HRMS (EI): *m*/*z* calcd. for $C_{16}H_{26}$ 218.20345; found 218.20459.

Dienyne 12b: butyllithium (0.8 mmol, 0.32 mL, 2.5 M in hexane) was added to a cold solution (–78 °C) of 1-alkyne **12a** (109 mg, 0.5 mmol) in THF (2 mL) under nitrogen. The resulting mixture was stirred for 1.25 h, freshly distilled $ClCO_2Me$ (0.8 mmol, 70 μL) was added, and the reaction mixture warmed to 20 °C. The mixture was then diluted with Et_2O (15 mL) and washed with water (10 mL). The aqueous phase was extracted with Et_2O (2 × 10 mL) and the combined organic layers washed with brine and dried with $MgSO_4$. The residue was purified by flash chromatography on silica gel (2% EtOAc in PE) to give 132 mg (95%) of **12b** as a colorless liquid. R_f = 0.20 (EtOAc/cyclohexane, 2:98). ^{1}H NMR: δ = 5.85–5.72 (m, 1 H), 5.09 (br. t, *J* = 6.0, 1 H), 5.03–4.93 (m, 2 H), 3.74 (s, 3 H), 2.15–2.00 (m, 4 H), 1.67 (s, 3 H), 1.61 (s, 3 H), 1.60–1.30 (m, 8 H), 1.21 (s, 3 H) ppm. ^{13}C NMR: δ = 154.3 (C), 138.3 (CH), 131.9 (C), 123.7 (CH), 114.7 (CH_2), 95.1 (C), 73.9 (C), 52.3 (CH_3), 40.7 (CH_2), 40.1 (CH_2), 35.0 (C), 33.9 (CH_2), 25.5 (CH_2), 25.4 (2 CH_2), 23.9 (CH_3), 23.4 (CH_3), 17.5 (CH_3) ppm. IR (neat): $\tilde{\nu}$ = 1714, 1641 cm^{-1}. CI MS (NH_3): *m*/*z* = 277 [M^+ + 1], 294 [M^+ + 18]. HRMS (EI): *m*/*z* calcd. for $C_{18}H_{28}O_2$ 276.20893; found 276.20950.

Bicyclic Diene 16a: The Grubbs catalyst **3** (5 mg, 5 mol-%) was added to a degassed solution of dienyne **12a** (22 mg, 0.1 mmol) in

dry CH_2Cl_2 (50 mL, 2×10^{-3} M) under nitrogen. The mixture was heated at reflux for 3 h then cooled to room temp. The solvent was removed and the residue submitted to flash chromatography on silica gel (PE) to give the bicyclic compound **16a** (14 mg, 86%) as a colorless oil. ^{1}H NMR: δ = 5.94 (dd, J = 9.6, 2.4 Hz, 1 H), 5.61 (br. t, J = 7.6 Hz, 1 H), 5.54 (t, J = 6.4 Hz, 1 H), 2.40–2.10 (m, 3 H), 2.10–2.00 (m, 1 H), 1.90–1.10 (m, 11 H), 1.02 (s, 3 H) ppm. ^{13}C NMR: δ = 144.6 (C), 132.2 (CH), 129.2 (CH), 124.9 (CH), 42.0 (CH_2), 38.8 (CH_2), 37.7 (C), 28.3 (CH_2), 27.5 (CH_2), 25.2 (CH_2), 22.5 (CH_2), 21.2 (CH_3) ppm. CI MS (NH_3): m/z = 163 [M^+ + 1], 180 [M^+ + 18]. HRMS (EI): m/z calcd. for $C_{12}H_{18}$ 162.14085; found 162.14067.

Dimeric Compound 17: This compound was formed when **16a** was submitted to the metathesis reaction at a concentration higher than 2.5×10^{-3} M. Colorless oil. ^{1}H NMR: δ = 5.92 (d, J = 12 Hz, 1 H), 5.91 (d, J = 12 Hz, 1 H), 5.85–5.78 (m, 1 H), 5.65–5.58 (m, 1 H), 5.61–5.59 (br. s, 1 H), 5.53 (t, J = 3 Hz, 1 H), 2.40–2.10 (m, 8 H), 2.10–1.78 (m, 6 H), 1.75–1.45 (m, 5 H), 1.35–1.25 (m, 5 H), 1.12 (s, 3 H), 1.09 (s, 3 H) ppm. ^{13}C NMR: δ = 148.0 (C), 147.2 (C), 129.8 (CH), 129.1 (CH), 128.7 (CH), 126.82 (CH), 126.79 (CH), 126.0 (CH), 48.8 (C), 48.7 (C), 41.0 (CH_2), 39.6 (CH_2), 39.0 (CH_2), 38.7 (CH_2), 33.3 (CH_2), 32.2 (CH_2), 30.0 (CH_2), 29.7 (CH_2), 29.6 (CH_2), 29.5 (CH_2), 27.6 (CH_3), 26.7 (CH_3), 23.4 (CH_2), 23.0 (CH_2) ppm. CI MS (NH_3): m/z = 325 [M^+ + 1]. HRMS (EI): m/z calcd. for $C_{24}H_{36}$ 324.28170; found 324.28195.

Bicyclic Diene 16b: Prepared from dienyne **12b** (70 mg, 0.11 mmol) by the same procedure as for **12a** (42 mg, 76%). Colorless oil. ^{1}H NMR: δ = 6.22 (br. s, 1 H), 5.90 (t, J = 6.4 Hz, 1 H), 3.74 (s, 3 H), 2.15–2.20 (m, 4 H), 1.90–1.10 (m, 8 H), 1.04 (s, 3 H) ppm. ^{13}C NMR: δ = 170.3, (C), 139.8 (C), 135.0 (C), 131.6 (CH), 129.8 (CH), 51.8 (CH_3), 40.1 (CH_2), 38.1 (CH_2), 37.9 (C), 27.1 (CH_2), 26.4 (CH_2), 24.1 (CH_2), 22.6(CH_2), 21.3 (CH_3) ppm. IR (CCl_4): $\tilde{\nu}$ = 1723 cm^{-1}. CI MS (NH_3): m/z = 221 [M^+ + 1], 238 [M^+ + 18]. HRMS (EI): m/z calcd. for $C_{14}H_{20}O_2$ 220.14633; found 220.14630.

Alder Ene Product 18: [$Pd(OAc)_2(PPh_3)_2$] (2 mg) was added to a degassed solution of dienyne **12a** (9 mg, 0.04 mmol) in dry toluene (0.2 mL) under nitrogen. The mixture was stirred at room temp. for 24 h, then the solvent was evaporated under vacuum. Purification by flash chromatography (PE) afforded 3 mg of **18** (33%) followed by 2 mg of **12a** (22%).

18: Colorless oil. ^{1}H NMR: δ = 5.90–5.65 (m, 1 H), 5.00 (d, J = 17 Hz, 1 H), 4.94 (d, J = 9.6 Hz, 1 H), 4.90–4.70 (m, 4 H), 3.25–3.10 (m, 1 H), 2.10–1.95 (m, 2 H), 1.80–1.65 (m, 2 H), 1.63 (s, 3 H), 1.60–1.20 (m, 8 H), 1.01 (s, 3 H) ppm. ^{13}C NMR: δ = 146.8 (C), 139.2(C), 118.0 (CH), 114.2 (CH_2), 112.4 (CH_2), 104.4 (CH_2), 54.4 (CH), 45.4 (C), 41.8 (CH_2), 37.4 (CH_2), 33.8 (CH_2), 29.8 (CH_2), 28.4 (CH_2), 27.5(CH_3), 24.3 (CH_2), 18.1 (CH_3) ppm. IR (CCl_4): $\tilde{\nu}$ = 3074, 1642 cm^{-1}. CI MS (NH_3): m/z = 219 [M^+ + 1]. HRMS (EI): m/z calcd. for $C_{16}H_{26}$ 218.20345; found 218.20306.

Compound 19: $PtCl_2$ (2 mg) was added to a degassed solution of dienyne **12a** (9 mg, 0.04 mmol) in dry toluene (0.3 mL) under nitrogen. The mixture was warmed to 60 °C for 2.5 h, then cooled to room temp. and the solvent evaporated under vacuum. Purification by flash chromatography (PE) afforded 8 mg of **19** (88%) as a colorless oil. ^{1}H NMR: δ = 5.90–5.70 (m, 1 H), 5.49 (s, 1 H), 5.44 (s, 1 H), 5.00 (d, J = 17 Hz, 1 H), 4.93 (d, J = 11 Hz, 1 H), 2.40–2.25 (m, 2 H), 2.15–1.95 (q, J = 8 Hz, 1 H), 1.82 (s, 3 H), 1.79 (s, 3 H), 1.60–1.50 (m, 1 H), 1.20–1.12 (m, 7 H), 1.10–1.05 (m, 1 H), 1.00 (s, 3 H) ppm. ^{13}C NMR: δ = 147.4 (C), 139.3 (CH), 136.2 (C), 125.8 (CH), 118.9 (CH), 114.1 (CH_2), 49.8 (C), 39.9 (CH_2), 36.0 (CH_2), 33.8 (CH_2), 30.4 (CH_2), 29.8 (CH_2), 26.9 (CH_3), 26.1 (CH_3), 24.3 (CH_2), 20.0 (CH_3) ppm. CI MS (NH_3): m/z = 219 [M^+ + 1]. HRMS (EI): m/z calcd. for $C_{16}H_{26}$ 218.20345; found 218.20355.

Synthesis of Compounds 24, 25, and 35–39

Alcohol 21: Prepared from tetrahydro-2*H*-pyran-2-ol[26] by Wittig reaction with the ylide of isopropyltriphenylphosphonium iodide, oxidation, and addition of homoallylmagnesium bromide to the corresponding aldehyde.[27] Colorless liquid. R_f = 0.20 (EtOAc/cyclohexane, 1:4). ^{1}H NMR: δ = 5.90–5.78 (m, 1 H), 5.13–5.08 (m, 1 H), 5.04 (qd, J = 17.2, 2.0 Hz, 1 H), 4.96 (br. d, J = 10.1 Hz, 1 H), 3.65–3.58 (br. s, 1 H), 2.25–2.08 (m, 2 H), 2.03–1.98 (m, 2 H), 1.68 (d, J = 1.0 Hz, 3 H), 1.59 (s, 3 H), 1.54–1.35 (m, 6 H) ppm. ^{13}C NMR: δ = 138.6 (CH), 131.0 (C), 124.4 (CH), 114.6 (CH_2), 71.4 (CH), 37.0 (CH_2), 36.4 (CH_2), 30.0 (CH_2), 27.9 (CH_2), 25.8 (CH_2), 25.6 (CH_3), 17.6 (CH_3) ppm. HRMS (EI): m/z calcd. for $C_{12}H_{22}O$ 182.16707; found 182.16632.

Nitrile 22: Tosyl chloride (1.97 g, 10.27 mmol) and 4-DMAP (20 mg, 0.16 mmol) were added to a solution of alcohol **21** (1.7 g, 9.33 mmol) in pyridine (9.5 mL) under argon at –10 °C. The reaction mixture was kept overnight at 6 °C under argon, then diluted with Et_2O (50 mL) and poured into a mixture of water and ice (100 mL). The aqueous phase was extracted with Et_2O (3×100 mL) and the combined organic layers washed with 10% HCl, saturated aqueous sodium hydrogen carbonate (10 mL) and brine (100 mL), dried ($MgSO_4$), and concentrated under reduced pressure. The crude product was purified by chromatography (EtOAc/cyclohexane, 10:90) to give 2.5 g (7.44 mmol, 79%) of the tosylate as a colorless oil. NaCN (420 mg, 8.34 mmol) was added to a solution of the tosylate (2.5 g, 7.44 mmol) in dry HMPA (8.5 mL) under argon. The reaction mixture was stirred for 18 h at room temperature, diluted with Et_2O (100 mL) and washed with H_2O (3×50 mL) and brine (50 mL), dried ($MgSO_4$), and concentrated under reduced pressure. The crude product was purified by chromatography on silica gel (EtOAc/cyclohexane, 10:90) to give 1.20 g (6.28 mmol, 67% 2 steps) of **22** as a colorless liquid. R_f = 0.80 (EtOAc/cyclohexane, 5:95). ^{1}H NMR: δ = 5.83–5.70 (m, 1 H), 5.12–5.02 (m, 3 H), 2.60–2.55 (m, 1 H), 2.15–2.12 (m, 2 H), 2.08–1.95 (m, 2 H), 1.80–1.25 (m, 6 H), 1.63 (s, 3 H), 1.60 (s, 3 H) ppm. ^{13}C NMR: δ = 136.4 (CH), 132.3 (C), 123.5 (CH), 122.0 (C), 116.1 (CH_2), 31.7 (CH_2), 31.4 (CH_2), 31.1 (CH_2), 30.8 (CH), 27.3 (CH_2), 27.2 (CH_2), 25.6 (CH_3), 17.6 (CH_3) ppm. IR (neat): $\tilde{\nu}$ = 2236, 1641 cm^{-1}. HRMS (EI): m/z calcd. for $C_{13}H_{21}N$ 191.16740; found 191.16626.

Aldehyde 23: Prepared from nitrile **22** by the same procedure as for **15** (1.70 g, 88%). Colorless liquid. R_f = 0.85 (EtOAc/cyclohexane, 1:9). ^{1}H NMR: δ = 9.58 (d, J = 3 Hz, 1 H), 5.83–5.70 (m, 1 H), 5.10–4.97 (m, 3 H), 2.35–2.22 (m, 1 H), 2.10–1.96 (m, 4 H), 1.80–1.30 (m, 6 H), 1.68 (s, 3 H), 1.59 (s, 3 H) ppm. ^{13}C NMR: δ = 205.0 (C), 137.7 (CH), 131.9 (C), 123.9 (CH), 115.3 (CH_2), 51.1 (CH), 31.1 (CH_2), 28.4 (CH_2), 28.0 (CH_2), 27.9 (CH_2), 27.1 (CH_2), 25.6 (CH_3), 17.6 (CH_3) ppm. IR (neat): $\tilde{\nu}$ = 1724, 1641 cm^{-1}. HRMS (EI): m/z calcd. for $C_{13}H_{22}O$ 194.16707; found 194.16779.

Alkyne 24: Prepared from **23** by the same procedure as for **12a** (610 mg, 58%) as a colorless liquid. R_f = 0.50 (pentane). ^{1}H NMR: δ = 5.88–5.75 (m, 1 H), 5.13–4.96 (m, 3 H), 2.45–2.18 (m, 3 H), 2.05 (s, 1 H), 2.02–1.98 (m, 1 H), 1.69 (s, 3 H), 1.61 (s, 3 H), 1.60–1.30 (m, 6 H) ppm. ^{13}C NMR: δ = 138.2 (CH), 131.4 (C), 124.4 (CH), 114.8 (CH_2), 87.6 (C), 69.3 (CH), 34.5 (CH_2), 34.1 (CH_2), 31.4 (CH_2), 30.9 (CH), 27.8 (CH_2), 27.4 (CH_2), 25.6 (CH_3), 17.6 (CH_3) ppm. IR (neat): $\tilde{\nu}$ = 3308, 1641 cm^{-1}. HRMS (EI): m/z calcd. for $C_{14}H_{22}$ 190.17215; found 190.17131.

Ester 25: Prepared from **24** by the same procedure as for **12b** (183 mg, 73%). Colorless oil. R_f = 0.50 (EtOAc/cyclohexane,

2.5:97.5). ^{1}H NMR: δ = 5.88–5.75 (m, 1 H), 5.08 (dt, J = 6.0, 1.2 Hz, 1 H), 5.03 (dd, J = 17.2, 1.5 Hz, 1 H), 4.97 (dd, J = 10.2, 1 H), 3.74 (s, 3 H), 2.48 (quint., J = 6.3 Hz, 1 H), 2.31–2.07 (m, 2 H), 2.02–1.94 (m, 2 H), 1.68 (s, 3 H), 1.62–1.37 (m, 6 H), 1.58 (s, 3 H) ppm. ^{13}C NMR: δ = 154.1 (C), 137.4 (CH), 131.7 (C), 124.0 (CH), 115.2 (CH_2), 92.3 (C), 74.1 (C), 52.3 (CH_3), 33.5 (CH_2), 33.2 (CH_2), 31.2 (CH_2), 31.0 (CH), 27.6 (CH_2), 27.3 (CH_2), 25.5 (CH_3), 17.5 (CH_3) ppm. IR (neat): $\tilde{\nu}$ = 1714, 1641 cm^{-1}. HRMS (EI): m/z calcd. for $C_{16}H_{24}O_2$ 248.17763; found 248.17830.

Alcohol 27: A solution of 1-bromo-5-pentene (9.4 g, 63 mmol) in THF (45 mL) was added to magnesium turnings (1.53 g, 63 mmol) in THF (5 mL). To initiate the reaction four drops of neat 1-bromo-5-pentene were added to the mixture and the remainder of the 1-bromo-5-pentene solution was then added dropwise over 15 min at a rate sufficient to maintain reflux without heating. The resulting solution was stirred under reflux for 60 min, cooled to room temp., and ethyl formate (2.02 g, 27.26 mmol) was added dropwise at this temperature. The reaction mixture was stirred under reflux for 1 h, cooled to 0 °C, quenched with sat. aq. NH_4Cl and the mixture stirred for 20 min. The aqueous phase was extracted with Et_2O (2 × 50 mL) and the combined organic layers washed with aqueous saturated sodium hydrogen carbonate solution and brine, dried ($MgSO_4$), filtered, and evaporated under reduced pressure. The crude product was purified by chromatography on silica gel (EtOAc/cyclohexane, 15:85) to give 4.63 g (87%) of **27** as a colorless liquid. R_f = 0.40 (EtOAc/cyclohexane, 15:85). ^{1}H NMR: δ = 5.87–5.73 (m, 2 H), 5.00 (qd, J = 17.1, 1.5 Hz, 2 H), 4.97–4.92 (m, 2 H), 3.62–3.58 (br. s, 1 H), 2.09–2.03 (m, 4 H), 1.57–1.38 (m, 8 H) ppm. ^{13}C NMR: δ = 138.6 (2 CH), 114.5 (2 CH), 71.6 (CH), 36.8 (2 CH_2), 33.7 (2 CH_2), 24.8 (2 CH_2) ppm.

Alcohol 28: Prepared from 1-bromo-6-hexene and ethyl formate by the same procedure as for **27** (4.68 g, 93%). Colorless liquid. R_f = 0.10 (EtOAc/cyclohexane, 1:9). ^{1}H NMR: δ = 5.88–5.74 (m, 2 H), 5.00 (qd, J = 17.1, 1.5 Hz, 2 H), 4.94 (qd, J = 12.3, 1.2 Hz, 2 H), 3.62–3.56 (br. s, 1 H), 2.10–2.03 (m, 4 H), 1.50–1.29 (m, 12 H) ppm. ^{13}C NMR: δ = 138.9 (2 CH), 114.3 (2 CH), 71.8 (CH), 37.3 (2 CH_2), 33.7 (2 CH_2), 28.9 (2 CH_2), 25.1 (2 CH_2) ppm. IR (neat): $\tilde{\nu}$ = 3355, 1641 cm^{-1}.

Nitrile 29: Prepared from **26**[28] by the same procedure as for **22** (2.10 g, 51%). Colorless liquid. R_f = 0.60 (EtOAc/cyclohexane, 1:9). ^{1}H NMR: δ = 5.90–5.72 (m, 2 H), 5.12–4.97 (m, 4 H), 2.63–2.56 (m, 1 H), 2.37–2.05 (m, 4 H), 1.80–1.43 (m, 6 H) ppm. ^{13}C NMR: δ = 137.6 (CH), 136.4 (CH), 121.9 (C), 116.2 (CH_2), 115.2 (CH_2), 33.0 (CH_2), 31.4 (CH_2), 31.3 (CH_2), 31.1 (CH_2), 30.7 (CH), 26.2 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 2237, 1641 cm^{-1}.

Nitrile 30: Prepared from **27** by the same procedure as for **22** (1.19 g, 61%). Colorless liquid. R_f = 0.40 (EtOAc/cyclohexane, 5:95). ^{1}H NMR: δ = 5.83–5.70 (m, 2 H), 5.02 (qd, J = 17.1, 1.5 Hz, 2 H), 4.99–4.94 (m, 2 H), 2.58–2.43 (m, 1 H), 2.11–2.07 (m, 4 H), 1.63–1.50 (m, 8 H) ppm. ^{13}C NMR: δ = 137.8 (2 CH), 122.2 (C), 115.4 (2 CH_2), 33.2 (2 CH_2), 31.7 (2 CH_2), 31.6 (CH), 26.4 (2 CH_2) ppm. IR (neat): $\tilde{\nu}$ = 2237, 1641 cm^{-1}.

Nitrile 31: Prepared from **28** by the same procedure as for **22** (2.80 g, 63%). Colorless liquid. R_f = 0.40 (EtOAc/cyclohexane, 5:95). ^{1}H NMR: δ = 5.85–5.72 (m, 2 H), 5.00 (qd, J = 17.1, 1.5 Hz, 2 H), 4.94 (qd, J = 12.3, 1.2 Hz, 2 H), 2.53–2.46 (br. s, 1 H), 2.10–2.03 (m, 4 H), 1.62–1.40 (m, 12 H) ppm. ^{13}C NMR: δ = 138.2 (2 CH), 122.1 (C), 114.7 (2 CH), 33.3 (2 CH_2), 32.1 (2 CH_2), 31.6 (CH), 28.3 (2 CH_2), 26.5 (2 CH_2) ppm. IR (neat): $\tilde{\nu}$ = 2237, 1641 cm^{-1}. HRMS (EI): m/z calcd. for $C_{14}H_{23}N$, 205.18305; found 205.18302.

Aldehyde 32: Prepared from nitrile **29** by the same procedure as for **15** (1.84 g, 86%). Colorless liquid. R_f = 0.51 (EtOAc/cyclohexane, 5:95). ^{1}H NMR: δ = 9.58 (d, J = 3 Hz, 1 H), 5.83–5.70 (m, 2 H), 5.00 (qd, J = 17.1, 1.5 Hz, 2 H), 4.99–4.94 (m, 2 H), 2.33–2.24 (m, 1 H), 2.09–2.02 (m, 4 H), 1.81–1.33 (m, 6 H) ppm. ^{13}C NMR: δ = 204.8 (C), 138.1 (CH), 137.6 (CH), 115.3 (CH_2), 114.9 (CH_2), 51.0 (CH), 33.6 (CH_2), 31.1 (CH_2), 28.1 (CH_2), 27.9 (CH_2), 26.1 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 1724, 1641 cm^{-1}.

Aldehyde 33: Prepared from **30** by the same procedure as for **15** (710 mg, 91%). Colorless liquid. R_f = 0.50 (EtOAc/cyclohexane, 5:95). ^{1}H NMR: δ = 9.55 (d, J = 3 Hz, 1 H), 5.83–5.70 (m, 2 H), 5.00 (qd, J = 17.1, 1.5 Hz, 2 H), 4.97–4.93 (m, 2 H), 2.30–2.20 (m, 1 H), 2.08–2.01 (m, 4 H), 1.70–1.26 (m, 8 H) ppm. ^{13}C NMR: δ = 205.1 (C), 138.1 (2 CH), 114.8 (2 CH_2), 51.6 (CH), 33.6 (2 CH_2), 28.1 (2 CH_2), 26.2 (2 CH_2) ppm. IR (neat): $\tilde{\nu}$ = 1724, 1641 cm^{-1}.

Aldehyde 34: Prepared from **31** by the same procedure as for **15** (1.89 g, 85%). Colorless liquid. R_f = 0.50 (EtOAc/cyclohexane, 5:95). ^{1}H NMR: δ = 9.56 (d, J = 3 Hz, 1 H), 5.85–5.71 (m, 2 H), 5.00 (qd, J = 17.1, 1.5 Hz, 2 H), 4.97–4.91 (m, 2 H), 2.27–2.17 (m, 1 H), 2.06–2.00 (q, J = 6.6 Hz, 4 H), 1.68–1.56 (m, 2 H), 1.48–1.23 (m, 10 H) ppm. ^{13}C NMR: δ = 205.3 (C), 138.6 (2 CH), 114.5 (2 CH_2), 51.8 (CH), 33.4 (2 CH_2), 28.9 (2 CH_2), 28.7 (2 CH_2), 26.5 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 1724, 1641 cm^{-1}. HRMS (EI): m/z calcd. for $C_{14}H_{24}O$ 208.18272; found 208.18226.

Alkyne 35: Prepared from **32** by the same procedure as for **12a** (300 mg, 61%). Colorless liquid. R_f = 0.60 (pentane). ^{1}H NMR: δ = 5.88–5.75 (m, 2 H), 5.05 (qd, J = 17.1, 1.8 Hz, 1 H), 5.02 (qd, J = 17.1, 1.8 Hz, 1 H), 5.00–4.94 (m, 2 H), 2.41–2.04 (m, 5 H), 2.07 (d, J = 2.4 Hz, 1 H), 1.68–1.43 (m, 6 H) ppm. ^{13}C NMR: δ = 138.6 (CH), 138.1 (CH), 114.8 (CH_2), 114.5 (CH_2), 87.5 (C), 69.4 (CH), 34.3 (CH_2), 34.2 (CH_2), 33.5 (CH_2), 31.4 (CH_2), 30.9 (CH), 26.5 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 3309, 1641 cm^{-1}.

Alkyne 36: Prepared from **33** by the same procedure as for **12a** (359 mg, 78%). Colorless liquid. R_f = 0.60 (pentane). ^{1}H NMR: δ = 5.88–5.75 (m, 2 H), 5.02 (qd, J = 17.1, 1.8 Hz, 2 H), 5.00–4.93 (m, 2 H), 2.39–2.30 (m, 1 H), 2.11–2.04 (m, 4 H), 2.05 (d, J = 2.1 Hz, 1 H), 1.68–1.41 (m, 8 H) ppm. ^{13}C NMR: δ = 138.7 (2 CH), 114.5 (2 CH_2), 87.8 (C), 69.2 (CH), 34.4 (2 CH_2), 33.5 (2 CH_2), 31.3 (CH), 26.5 (2 CH_2) ppm. IR (neat): $\tilde{\nu}$ = 3307, 1641 cm^{-1}. HRMS (EI): m/z calcd. for $C_{13}H_{20}$ 176.15650; found 176.15713.

Alkyne 37: Prepared from **34** by the same procedure as for **12a** (864 mg, 58%). Colorless liquid. R_f = 0.60 (pentane). ^{1}H NMR: δ = 5.89–5.76 (m, 2 H), 5.02 (qd, J = 17.1, 1.8 Hz, 2 H), 4.94 (dtd, J = 10.2, 1.8, 1.2 Hz, 2 H), 2.35–2.29 (m, 1 H), 2.11–2.04 (m, 5 H), 1.57–1.33 (m, 12 H) ppm. ^{13}C NMR: δ = 138.9 (2 CH), 114.3 (2 CH_2), 88.0 (C), 69.1 (CH), 34.8 (2 CH_2), 33.7 (2 CH_2), 31.5 (CH), 28.8 (2 CH_2), 26.7 (2 CH_2) ppm. IR (neat): $\tilde{\nu}$ = 3309, 1641 cm^{-1}. HRMS (EI): m/z calcd. for $C_{15}H_{24}$ 204.18780; found 204.18870.

Ester 38: Prepared from **36** by the same procedure as for **12b** (178 mg, 76%). Colorless oil. R_f = 0.54 (EtOAc/cyclohexane, 5:95). ^{1}H NMR: δ = 5.85–5.71 (m, 2 H), 5.00 (qd, J = 17.4, 1.5 Hz, 2 H), 5.00 (qd, J = 10.2, 1.0 Hz, 2 H), 3.75 (s, 3 H), 2.51–2.43 (m, 1 H), 2.09–2.03 (m, 4 H), 1.64–1.41 (m, 8 H) ppm. ^{13}C NMR: δ = 154.2 (C), 138.2 (2 CH), 114.8 (2 CH_2), 92.5 (C), 74.1 (C), 52.3 (CH_3), 33.5 (2 CH_2), 33.4 (2 CH_2), 31.5 (CH), 26.4 (2 CH_2) ppm. IR (neat): $\tilde{\nu}$ = 1713, 1641 cm^{-1}.

Ester 39: Prepared from **37** by the same procedure as for **12b** (320 mg, 83%). Colorless oil. R_f = 0.21 (EtOAc/cyclohexane, 1:99). ^{1}H NMR: δ = 5.86–5.73 (m, 2 H), 5.03–4.91 (m, 4 H), 3.75 (s, 3 H), 2.51–2.42 (m, 1 H), 2.09–2.02 (m, 4 H), 1.51–1.36 (m, 12 H)

ppm. ^{13}C NMR: δ = 154.2 (C), 138.6 (2 CH), 114.4 (2 CH_2), 92.8 (C), 73.9 (C), 52.4 (CH_3), 33.9 (2 CH_2), 33.5 (2 CH_2), 31.7 (CH), 28.6 (2 CH_2), 26.7 (2 CH_2) ppm. HRMS (EI): *m*/*z* calcd. for $C_{17}H_{26}O_2$ 262.19328; found 262.19552.

Typical Procedure for the Metathesis Reaction of Dienynes 24, 35, 38, and 39

Bicyclic Compound 40: Catalyst **3** (62 mg, 7.5 mol-%) was added to a degassed solution of trienyne **24** (200 mg, 1.05 mmol) in dry CH_2Cl_2 (11.3 mL) under argon. The mixture was heated at reflux for 4 h. The solvent was removed and the residue was purified by flash chromatography on Florisil (pentane) to give **40** (84 mg, 59%) as a colorless liquid. R_f = 0.74 (pentane). ^1H NMR: δ = 6.22 (d, *J* = 12.0 Hz, 1 H), 5.66–5.56 (m, 2 H), 2.65–2.60 (m, 1 H), 2.47–1.19 (m, 10 H) ppm. ^{13}C NMR: δ = 146.8 (C), 130.9 (CH), 129.7 (CH), 125.9 (CH), 48.6 (CH), 34.7 (CH_2), 33.6 (CH_2), 31.3 (CH_2), 31.0 (CH_2), 27.4 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 2922, 1455 cm^{-1}. HRMS (EI): *m*/*z* calcd. for $C_{10}H_{14}$ 134.10955; found 134.10983.

Metathesis of 35. Formation of Bicyclic Compounds 40 and 41: Using the same procedure as for **40** with catalyst **2**, **35** afforded an inseparable mixture of **40 and 41** (1:1; 118 mg, 95%). Colorless liquid. R_f = 0.74 (pentane). ^1H NMR: δ = 6.02 (d, *J* = 9.6 Hz, 1 H), 5.71–5.62 (m, 1 H), 5.50–5.44 (br. s, 1 H), 2.47–1.16 (m, 11 H) ppm. ^{13}C NMR: δ = 137.6 (C), 129.5 (CH), 127.2 (CH), 123.5 (CH), 35.7 (CH), 30.7 (CH_2), 30.5 (CH_2), 30.2 (CH_2), 26.0 (CH_2), 22.6 (CH_2) ppm.

Diene 42: Prepared from **24** and catalyst **2** by the same procedure as for **40**. Yield: 168 mg (84%). Colorless liquid. R_f = 0.72 (pentane). ^1H NMR: δ = 6.46 (dd, *J* = 17.7, 10.8 Hz, 1 H), 5.70 (s, 1 H), 5.17–5.03 (m, 3 H), 2.83 (t, *J* = 7.5 Hz, 1 H), 2.48–2.25 (m, 2 H), 2.10–1.98 (m, 3 H), 1.77–1.70 (m, 1 H), 1.71 (s, 3 H) 1.63 (s, 3 H), 1.47–1.20 (m, 4 H) ppm. ^{13}C NMR: δ = 146.6 (C), 132.9 (CH), 131.1 (C), 130.4 (CH), 124.9 (C), 113.3 (CH_2), 43.3 (CH), 32.8 (CH_2), 31.0 (CH_2), 29.8 (CH_2), 28.2 (CH_2), 27.8 (CH_2), 25.6 (CH_3), 17.6 (CH_3) ppm. IR (neat): $\tilde{\nu}$ = 1636 cm^{-1}.

Ester 43: Prepared from **25** by the same procedure as for **40**. Yield: 55 mg (73%). Colorless oil. R_f = 0.30 (EtOAc/cyclohexane, 1:99). ^1H NMR: δ = 6.11–6.09 (br. s, 1 H), 6.02 (s, 1 H), 5.56 (s, 1 H), 5.12–5.07 (m, 1 H), 3.78 (s, 3 H), 2.91–2.87 (m, 1 H), 2.51–2.30 (m, 2 H), 2.10–1.90 (m, 2 H), 1.69–1.12 (m, 6 H), 1.68 (d, *J* = 0.9 Hz, 3 H) 1.59 (s, 3 H) ppm. ^{13}C NMR: δ = 167.6 (C), 142.6 (C), 136.8 (C), 131.6 (CH), 131.3 (C), 124.7 (CH_2), 123.0 (CH_2), 51.7 (CH_3), 45.2 (CH), 32.7 (CH_2), 31.7 (CH_2), 29.3 (CH_2), 28.1 (CH_2), 27.8 (CH_2), 25.6 (CH_3), 17.6 (CH_3) ppm. IR (neat): $\tilde{\nu}$ = 1723, 1640 cm^{-1}. HRMS (EI): *m*/*z* calcd. for $C_{16}H_{24}O_2$ 248.17763; found 248.17757.

Metathesis Reaction of Dienyne 25. Formation of Diels–Alder Compound 44: Grubbs' first-generation catalyst **2** (25 mg, 0.03 mmol, 10 mol-%) was added to a degassed solution of trienyne **25** (75 mg, 0.3 mmol) in dry CH_2Cl_2 (7.8 mL) under argon and the mixture was heated at reflux for 3 h. The solvent was then removed and the residue was purified by flash chromatography on silica gel (EtOAc/cyclohexane, 1:99 to 2:98) to give 21 mg of ester **43** (0.08 mmol, 28%) and 20 mg of **44** (0.04 mmol, 27%) as colorless oils. R_f = 0.25 (EtOAc/cyclohexane, 1:99). ^1H NMR: δ = 5.48–5.45 (br. s, 1 H), 5.12 (t, *J* = 7.2 Hz, 1 H), 5.09 (t, *J* = 7.2 Hz, 1 H), 3.72 (s, 3 H), 3.69 (s, 3 H), 3.35–3.22 (br. s, 1 H), 2.91 (t, *J* = 9 Hz, 1 H), 2.62–2.50 (br. s, 1 H), 2.34–2.12 (m, 5 H), 2.03–1.00 (m, 19 H), 1.69 (s, 6 H) 1.60 (s, 6 H) ppm. ^{13}C NMR: δ = 176.2 (C), 167.7 (C), 161.9 (C), 143.0 (C), 131.3 (C), 131.2 (C), 127.5 (CH), 124.9 (CH), 124.7 (CH), 120.1 (C), 51.6 (CH_3), 51.0 (CH_3), 49.4 (C), 47.9 (CH), 47.3 (CH), 41.9 (CH), 36.2 (CH_2), 33.5 (CH_2), 30.5 (CH_2), 30.3 (CH_2), 29.0 (CH_2), 28.3 (CH_2), 28.2 (2 CH_2), 27.8 (CH_2), 25.7 (2 CH_2), 25.6 (2 CH_3), 23.6 (CH_2), 17.7 (2 CH_3) ppm. IR (neat): $\tilde{\nu}$ = 1732, 1714, 1648 cm^{-1}. CI MS (NH_3): *m*/*z* = 497 [M^+ + 1], 514 [M^+ + 18]. HRMS (EI): *m*/*z* calcd. for $C_{32}H_{48}O_4$ 496.35526; found 496.35359.

Bicyclic Compound 45: Prepared by the metathesis reaction of **36**. Yield: 26 mg (100%). Colorless liquid. R_f = 0.72 (pentane). ^1H NMR: δ = 5.96 (d, *J* = 12.0 Hz, 1 H), 5.62 (s, 1 H), 5.55 (dt, *J* = 12.0, 5.7 Hz, 1 H), 2.41–2.31 (m, 2 H), 2.10–2.08 (m, 3 H), 1.83–1.25 (m, 8 H) ppm. ^{13}C NMR: δ = 140.5 (C), 133.8 (CH), 128.5 (CH), 128.3 (CH), 37.6 (CH), 34.5 (CH_2), 30.8 (CH_2), 28.3 (CH_2), 27.5 (CH_2), 26.1 (CH_2), 20.3 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 3011, 2919, 1450 cm^{-1}.

Bicyclic Compound 46: Prepared from **38**. Yield: 53 mg (34%). Colorless oil. R_f = 0.35 (EtOAc/cyclohexane, 5:95). ^1H NMR: δ = 6.79 (t, *J* = 6.3 Hz, 1 H), 5.74 (t, *J* = 3.9 Hz, 1 H), 3.71 (s, 3 H), 2.40–2.05 (m, 5 H), 1.80–1.45 (m, 8 H) ppm. ^{13}C NMR: δ = 169.0 (C), 140.2 (CH), 137.3 (C), 134.8 (C), 129.1 (CH), 51.7 (CH_3), 36.6 (CH), 35.8 (CH_2), 29.7 (CH_2), 28.8 (CH_2), 25.6 (CH_2), 24.9 (CH_2), 17.7 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 2928, 1715, 1652 cm^{-1}.

Metathesis Reaction of Dienyne 37. Formation of Dimeric Compound 47: Grubbs' second-generation catalyst **3** (30 mg, 0.03 mmol, 10 mol-%) was added to a degassed solution of trienyne **37** (60 mg, 0.30 mmol) in dry CH_2Cl_2 (32 mL) under argon and the mixture was heated at reflux for 3 h. The solvent was removed and the residue was purified by flash chromatography on silica gel (pentane) to give 27 mg of **47** (0.076 mmol, 51% from **37**) as an inseparable mixture (1:1) of two diastereomers (white solid). M.p. 122–125 °C (recryst. from Et_2O). R_f = 0.65 (pentane). ^1H NMR: δ = 5.99 (d, *J* = 15.6 Hz, 1 H), 5.98 (d, *J* = 15.3 Hz, 1 H), 5.79 (dd, *J* = 8.0, 6.0 Hz, 1 H), 5.75 (dd, *J* = 8.0, 5.2 Hz, 1 H), 5.60–5.56 (m, 2 H), 2.78–2.73 (m, 1 H), 2.67–2.65 (m, 1 H), 2.30–2.02 (m, 8 H), 1.83–1.70 (m, 8 H), 1.60–1.20 (m, 16 H) ppm. ^{13}C NMR: δ = 145.7 (C), 145.6 (C), 136.0 (CH), 135.8 (CH), 130.0 (CH), 129.4 (CH), 126.7 (2 CH_2), 38.8 (CH), 37.8 (CH), 33.1 (CH_2), 32.77 (CH_2), 32.71 (CH_2), 32.54 (CH_2), 32.41 (CH_2), 32.30 (CH_2), 29.8 (CH_2), 29.7 (CH_2), 28.2 (2 CH_2), 28.1 (CH_2), 27.8 (CH_2), 27.7 (CH_2), 27.6 (CH_2), 26.5 (CH_2), 26.4 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 3022, 2921, 1640 cm^{-1}. EI MS: *m*/*z* 352 (10) [M^+], 67 (100). HRMS (EI): *m*/*z* calcd. for $C_{26}H_{40}$ 352.31300; found 352.31243.

Ester 48: Prepared from **39**. Yield: 70 mg (71%). Colorless oil. R_f = 0.22 (EtOAc/cyclohexane, 2:98). ^1H NMR: δ = 5.90 (d, *J* = 1.8 Hz, 1 H), 5.83–5.73 (m, 2 H), 5.49 (d, *J* = 1.8 Hz, 1 H), 5.01–4.90 (m, 2 H), 3.76 (s, 3 H), 2.35–2.24 (m, 1 H), 2.21–2.16 (m, 2 H), 2.06–2.00 (m, 2 H), 1.72–1.65 (m, 4 H), 1.51–1.12 (m, 8 H) ppm. ^{13}C NMR: δ = 168.1 (C), 146.1 (C), 139.1 (C), 131.1 (CH), 123.1 (CH_2), 114.2 (CH_2), 51.8 (CH_3), 41.6 (CH), 33.7 (CH_2), 30.3 (CH_2), 29.5 (CH_2), 29.1 (CH_2), 28.0 (CH_2), 27.33 (CH_2), 27.30 (CH_2), 26.0 (CH_2) ppm. IR (neat): $\tilde{\nu}$ = 1723, 1640 cm^{-1}.

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