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Highly Regio- and Stereocontrolled Formation of Functionalized Tricyclo[4.2.1.0^{2,8}]non-3-enes

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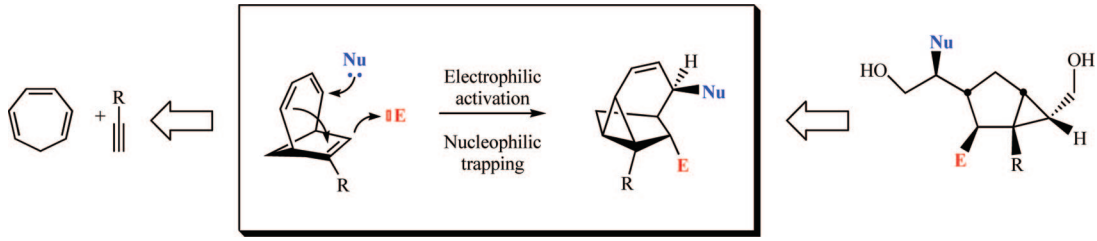
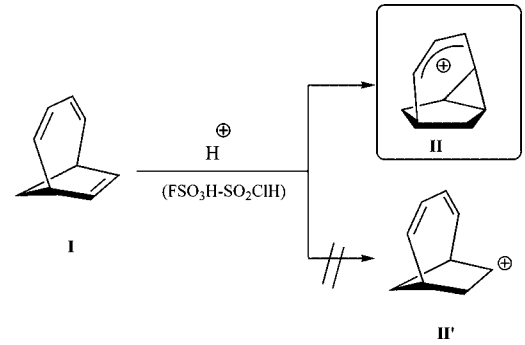


The electrophilic activations of bicyclo[4.2.1]nonatrienes by 4-isopropyl-1,2,4-triazolinedione, *N*-iodosuccinimide, or an epoxidation/acidic ring-opening sequence is reported. The subsequent in situ trappings by water, alcohols, or benzoic acids led to original tricyclo[4.2.1.0^{2,8}]non-3-enes with high regio- and stereoselectivities. The synthetic potentiality of these synthons is illustrated by the straightforward access to a fused cyclopropane featuring six consecutive controlled stereocenters.

Introduction

The bicyclo[4.2.1]nonane ring is a key pattern of several terpenoids and their metabolites, such as mediterranneols or longifolane derivatives.[1] In marked contrast, whereas synthetic accesses to these molecules have been intensively studied,[2,3] very simple synthons featuring a bicyclo[4.2.1]nonanoid squeleton have been scarcely exploited in synthesis. For instance, the reactivity of bicyclo[4.2.1]nonatrienes, which are readily available from metal-catalyzed [6 + 2] cycloaddition between cycloheptatriene and alkynes,[4,5] remains almost unexplored.[6] In 1970, Winstein et al. reported that the isolated double bond of the parent bicyclo[4.2.1]nonatriene **I** could be selectively protonated in a superacid medium.[7] Formally, the formed species is a bicyclo[4.2.1]nona-2,4-dien-7-yl cation (structure **II′**, Scheme 1). However, NMR studies clearly demonstrated the

SCHEME 1. Generation and Structure of Cation II from Bicyclo[4.2.1]nonatriene I in a Superacid Medium



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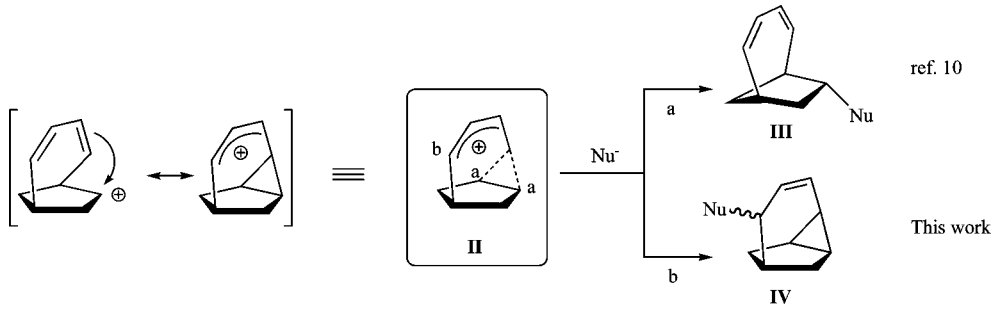
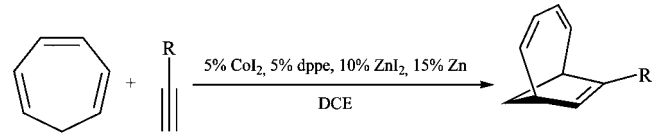
SCHEME 2. Nucleophilic Trapping of Ambiphilic Cation II



participation of the homoconjugated diene moiety, and this compound is better described as a higher symmetrical allylcyclopropane cation **II**. The resulting structure is undoubtedly original: rare and anecdotic syntheses of tricyclo-[4.2.1.0^{2,8}]nonanoid backbones have been reported in the literature.[8]

Cation **II** is related to the well-known methylenecyclopropyl cation.[9] Thus, its noteworthy stability is clearly explained by its constrained geometry, which is ideal for an efficient overlapping of the π*-system of the allylic moiety and the electron-rich σ_{cc} orbitals of the cyclopropyl substituent. Two mesomeric structures, which are displayed in Scheme 2, illustrate the subsequent ambiphilicity of the bridged symmetrical cation **II** which should be attacked by a nucleophile on the activated cyclopropane ring (activated sites are quoted "a" in Scheme 2) or on the allylic position (quoted "b"), affording respectively bicyclo[4.2.1]nonadienes **III** and tricyclo[4.2.1.0^{2,8}]non-3-enes **IV**. Winstein et al. failed to trap **II**, certainly because of the harsh acidic experimental conditions. However, in 1994, Paquette et al. reported a softer generation of **II** from the bicyclo[5.1.1]nona-1,4-dien-3-one and its in situ trapping with acetate, which afforded a bicyclo[4.2.1]nona-1,3-diene-7-yl acetate of type **III**.[10] To our knowledge, a nucleophilic attack on the allylic moiety of **II** to afford the original structure **IV** has not been reported to date.

SCHEME 3. Cobalt-Catalyzed [6 + 2] Cycloaddition of Cycloheptatriene with Alkynes



1a: R = Ph
1b: R = $SiMe_3$
1c: R = *n*-Bu

In this paper, we report various electrophilic activations of bicyclo[4.2.1]nonatrienes and the subsequent trapping with nucleophiles, leading to tricyclo[4.2.1.0^{2,8}]non-3-enes. These compounds are obtained with high regio- and stereoselectivities. The synthetic interest of these synthons is illustrated by the straightforward synthesis of a fused highly functionalized cyclopropane featuring six consecutive controlled stereocenters.

Results and Discussion

We first synthesized simple 7-substituted bicyclo[4.2.1]nonatrienes as model substrates. These compounds **1a**−**c** are readily available from cycloheptatriene and terminal alkynes through our recently reported cobalt-catalyzed [6 + 2] cycloaddition (Scheme 3).[5]

In a preliminary attempt to activate the isolated double bond of **1a**, we used the 4-isopropyl-1,2,4-triazolinedione (*i*-PrTAD)[11,12] in a $CHCl_3$/EtOH mixture (Scheme 4, first example). The quantitative formation of compound **2** was observed when warming the solution at 40 °C for 24 h. After purification by column chromatography, this product was isolated as a single diastereoisomer in nearly quantitative yield.

The NMR spectra clearly indicated that **2** featured an ethoxy and a nonsymmetrical 4-isopropyl-1,2,4-triazolidinedione moiety, so that one molecule of *i*-PrTAD and one of ethanol reacted with **1a**. The presence of only two olefinic protons was in favor of a structure related to **IV**, rather than **III**. This was confirmed by the X-ray analysis of a monocrystal of **2**, which appeared to be a 1-phenyl-5-ethoxy-9-triazolidinedione tricyclo[4.2.1.0^{2,8}]non-3-ene (see the Supporting Information).

A similar electrophilic activation could also be performed with a halonium reactant. Indeed *N*-iodosuccinimide (NIS) reacted with **1b** in methanol to afford **3** with 33% yield after

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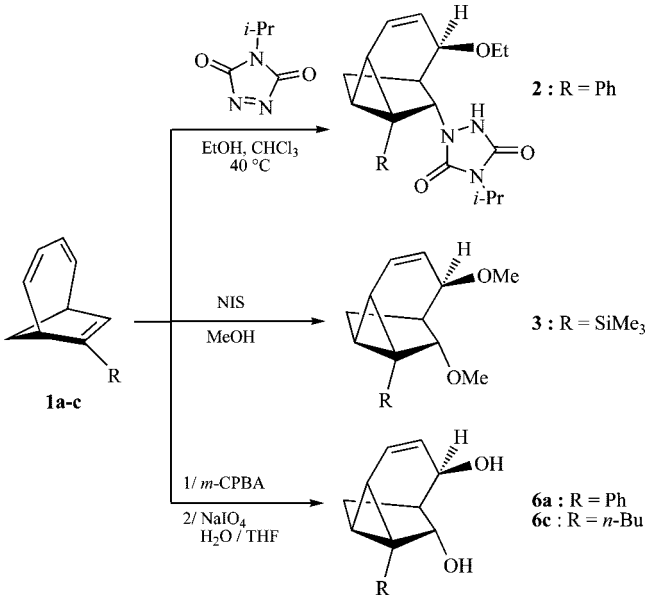
SCHEME 4. Electrophilic Activation and Nucleophilic Trapping of 1a−c



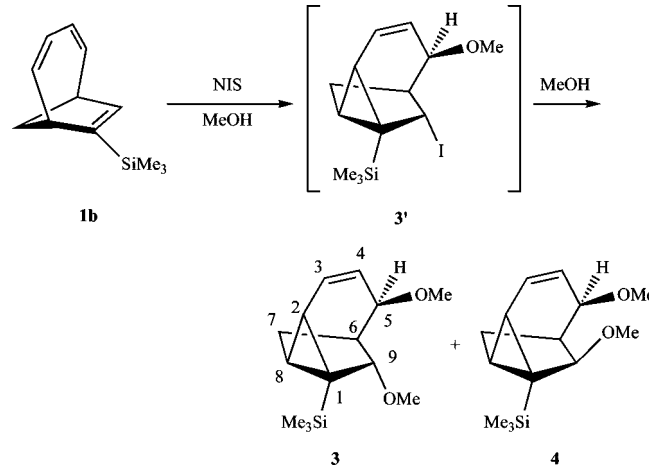
purification by column chromatography (Scheme 4, second example). NMR spectra of **3** displayed signals of two methoxy substituents, so that 2 equiv of methanol reacted with **1b**. Furthermore, its backbone was clearly related to the tricyclo-[4.2.1.0^{2,8}]non-3-ene structure of **2**. In particular, the vinylcyclopropane moieties featured similar chemical shifts and coupling constants. The stereochemistry at position 5 was confirmed by a NOESY experiment, which indicated that H5 is next to H7, no correlation being observed between H7 and methoxy substituents (see the Supporting Information).

The NMR analysis of the crude product revealed the formation of a byproduct **4**, the diastereomeric *ratio* **3**:**4** being 3:1. Compounds **3** and **4** are clearly C9-epimers because they mostly differ from the coupling constant between protons H6 and H9 (Scheme 5). In the major diastereoisomer **3**, H6 and H9 are *trans*,[13] as indicated by the absence of coupling between these protons in ^{1}H NMR (For a tricyclo[4.2.1.0^{2,8}]non-3-ene skeleton, the corresponding dihedral angle is then close to 90°, as indicated by the X-ray structure of **2**). For **4**, $J_{H6,H9}$ (2.4 Hz) is consistent with a *cis*[13] relationship (dihedral angle about 10° in **2**).

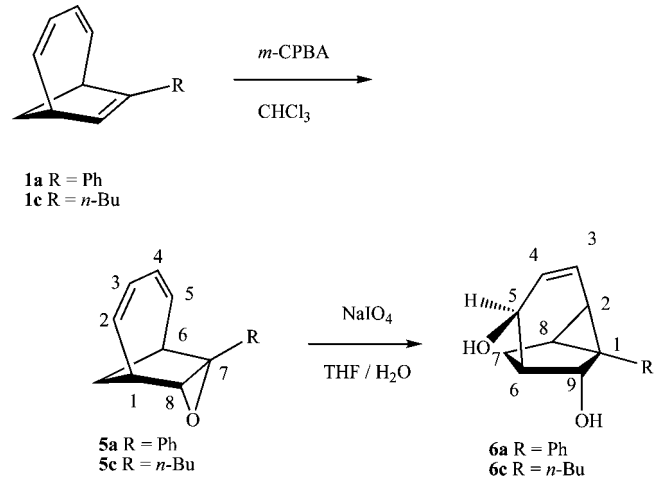
A two-step process can rationalize the formation of **3** and **4** (Scheme 5). First the electrophilic activation of **1b** and the trapping of the resulting iodinated carbocation by methanol could lead to **3′**, which is related to compound **2**. However, this compound could not be isolated: the labile iodide was immediately substituted by methanol and afforded compounds **3** and **4**. This latter step was not stereoselective because it probably proceeded through an S_N1 process. Indeed, the corresponding secondary carbocation, which results from the departure of the iodide anion, is stabilized both by the cyclopropyl substituent and the β-silyl group. We considered if a brominated derivative relative to **3′** would be less reactive toward substitution by methanol and if we could isolate it. Unfortunately, **1b** did not reacted cleanly with NBS or bromine. Furthermore, no clean reaction was observed with **1a**, even when NIS was used.

(13) The *trans* and *cis* configurations are defined relatively to the five-membered ring C1−C8−C7−C6−C9.

SCHEME 5. Synthesis and Structures of 3 and 4



SCHEME 6. Epoxidation Followed by Acidic Hydrolysis of 1a



At this point, although the possibility of synthesizing tricyclo[4.2.1.0^{2,8}]non-3-enes from bicyclo[4.2.1]nonatrienes was demonstrated, a more efficient route to these products was desirable. Considering that protonated epoxides are formally β-hydroxycarbocations, we turned our attention to an alternative two-step activation of trienes **1a**−**c**. First, **1a** was selectively transformed with *m*-CPBA into epoxide **5a** as a single diastereoisomer. ^{1}H NMR spectra clearly showed the characteristic signals of the diene moiety, so that the epoxidation selectively occurred on the isolated double bond. The *trans* relationship between H1 and H8 was deduced from their small coupling constant $J_{H1,H8}$: the epoxidation occurred unsurprisingly on the *exo* face of the CC double bond. Second, we proceeded to the soft acidic hydrolysis of epoxide **5a.** Gratifyingly, we observed the formation of 1-phenyl-5,9-dihydroxytricyclo[4.2.1.0^{2,8}]non-3-ene **6a** as a single diastereoisomer, which was isolated with 77% yield. The same sequence afforded 1-*n*-butyl-5,9-dihydroxytricyclo[4.2.1.0^{2,8}]non-3-ene **6c** in 66% yield (Scheme 6).

We briefly explored the reactivity of diol **6a** (Scheme 7). Treatment by NaH and MeI led to the protected diol **7** (73% yield). Of note, **7** could not be obtained through the electrophilic activation of **1a** by a halonium reactant: no clean reaction was observed when **1a** was reacted with NIS in methanol. The reductive ozonolysis of the vinylcyclopropane **7** afforded the diversely functionalized bicyclo[3.1.0]hexane **8** in 83% yield.

SCHEME 7. Chemical Transformations of 6a

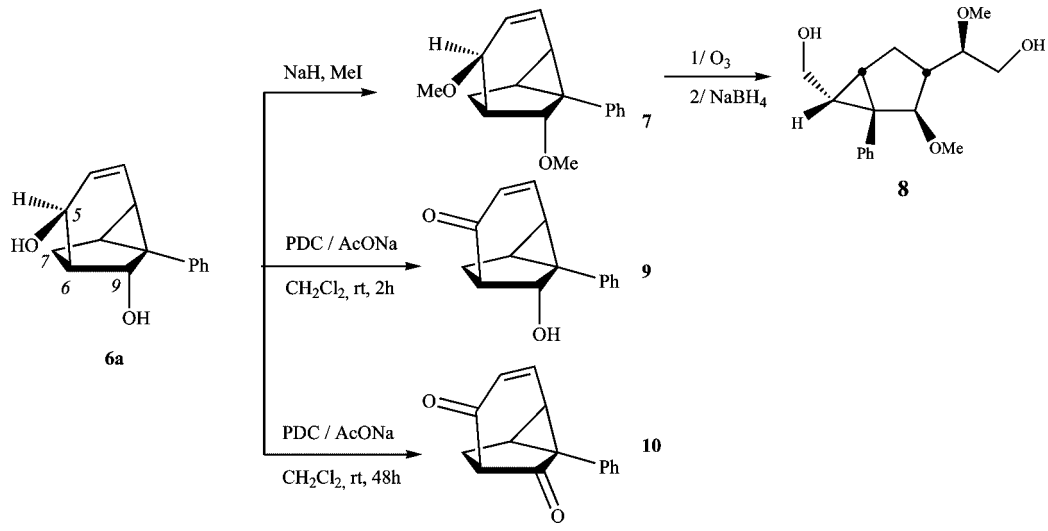
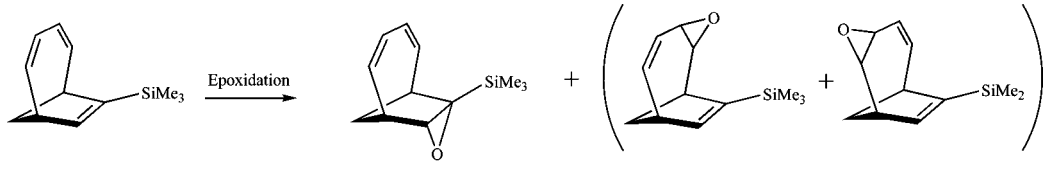


TABLE 1. Epoxidation of 7-Trimethylsilylbicyclo[4.2.1]nonatriene 1b



1b **5b** **11** **12**

entry	oxidizing agent	conditions	conversion[a] (%)	**5b**:(**11**, **12**) ratio[a]
1	*m*-CPBA	$NaHCO_3$, $CHCl_3$, 0 °C, 15 min	89	57:43
2	*m*-CPBA	$NaHCO_3$, $CHCl_3$, −40 °C, 15 min	66	49:51
3	*m*-CPBA	$NaHCO_3$, $CHCl_3$, 40 °C, 15 min	80	55:45
4	*m*-CPBA	$NaHCO_3$, H_2O, 0 °C, 25 min, then rt, 25 min	82	58:42
5	*m*-CPBA	$NaHCO_3$, THF, 0 °C, 30 min	60	55:45
6	*m*-CPBA	$NaHCO_3$, toluene, −78 °C, 30 min	27	62:38
7	*m*-CPBA	$NaHCO_3$, toluene, 0 °C, 30 min	88	68:32
8	Oxone	phosphate buffer (pH = 7.5), 18-crown-6, acetone/H_2O	100	0:100

[a] Measured on the crude mixture by means of ^{1}H NMR.

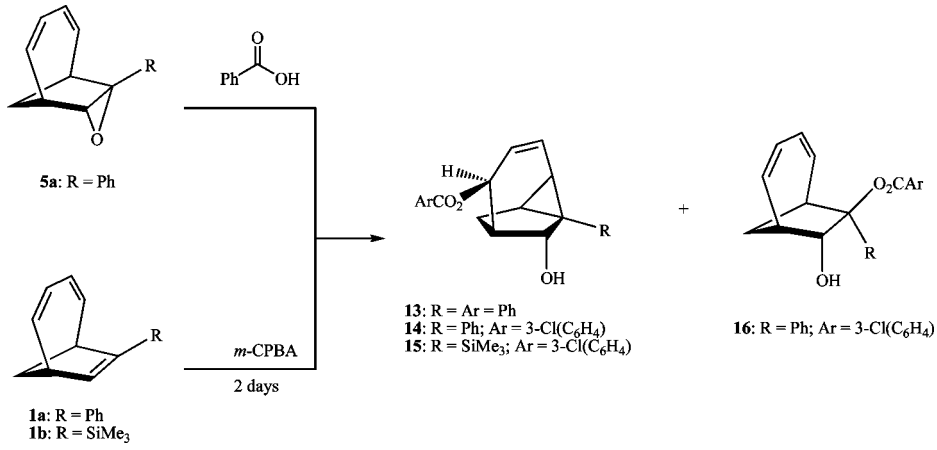
The allylic alcohol of **6a** could be selectively oxidized by PDC to afford enone **9** with 74% yield. The full oxidation of **6a** can proceed up to dione **10** with 96% yield.

The tricyclo[4.2.1.0^{2,8}]non-3-enoid structure of **10**, and consequently those of the related compounds **6a**−**c**, **7**, and **9**, was confirmed by X-ray analysis (see the Supporting Information). In the ^{1}H NMR spectra of compounds **6**−**9**, the absence of a coupling constant between H6 and H9 is consistent with a *trans* relationship between these two protons. In addition, a NOESY experiment demonstrated the spatial proximity of hydrogens H5 and H7 in diol **6a**, so that the stereochemistry at position 5 is identical to those previously observed for compounds **2**, **3**, and **4**.

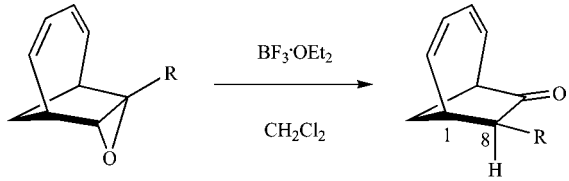
We met the first limitation of this two-step sequence when attempting the selective epoxidation of 7-trimethylsilylbicyclo[4.2.1]nonatriene **1b**. Indeed, under standard conditions (entry 1, Table 1), we obtained a 6:4 mixture of the desired epoxide and epoxides **11** and **12**, which resulted from the epoxidation of the diene moiety. We tried to improve this *ratio* by changing the experimental conditions. The temperature appeared to have no significant influence (entries 1−3, 6, and 7). A 7:3 *ratio* was finally obtained by using toluene as the solvent (entry 7), and epoxide **5b** was isolated in 60% yield after purification by column chromatography. When Oxone was used as oxidant, only undesired epoxides **11** and **12** were obtained (entry 8).

A second limitation of this method arose when considering the ring-opening of **5a** with benzoic acid, which resulted in the formation of a complex mixture of products. After purification on column chromatography, the expected tricyclo[4.2.1.0^{2,8}]non-3-en-5-yl benzoate **13** was finally isolated with a poor 29% yield (Scheme 8). As epoxidation by *m*-CPBA affords epoxides and *m*-chlorobenzoic acid, similar compounds could be directly obtained from trienes **1a**,**b**. Indeed, once epoxides **5a**,**b** were formed in $CHCl_3$, they slowly (2−3 days) evolved into tricyclo[4.2.1.0^{2,8}]non-3-en-5-yl *m*-chlorobenzoates **14** and **15**. Compound **15** was obtained with a low 12% yield, which can be attributed to the poor selectivity of the epoxidation step (theorical yield: 50%). Concerning adduct **14**, the analysis of the crude mixture indicated the formation of a second compound **16** in a 1:1 ratio. Isomers **14** and **16** were separated by flash chromatography on silica gel (27% and 26% yield), and **16** was identified, by means of ^{1}H and ^{13}C NMR, and featured the bicyclo[4.2.1]nonadiene structure resulting from the acid-catalyzed 1,2-ring-opening of epoxide **5a**. This competitive 1,2-addition is clearly related to the trapping of cation **II** by acetate, which was previously reported by Paquette.[10] Thus, although

SCHEME 8. Reaction of Epoxides 5a,b with Benzoic Acids



SCHEME 9. Evolution of Epoxide 5a,b in the Presence of a Lewis Acid

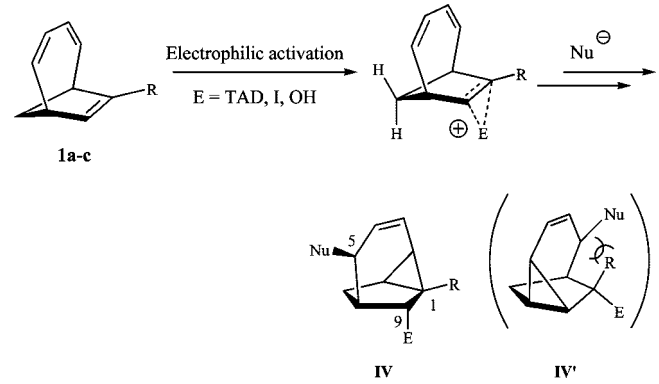


the factors that control the regioselectivity of the nucleophilic ring-opening of **5a**,**b** are not clearly understood yet, both the nature of the nucleophile and the R7-substituent of the bicyclo[4.2.1]nonatriene reactant seem to be critical.

In the absence of a nucleophile, Lewis acids usually catalyze rearrangements of epoxides. When $BF_3 \cdot OEt_2$ (0.2 equiv) was added to epoxide **5a** at −78 °C, we observed the formation of a complex mixture of oligomers. When the addition was performed at room temperature with 1.1 equiv of $BF_3 \cdot OEt_2$, ketone **17a** was finally isolated with 25% yield after purification by chromatography (Scheme 9). Addition of a catalytic amount of $BF_3 \cdot OEt_2$ on epoxide **5b** afforded a cleaner reaction, according to ^{1}H NMR of the crude product. However, the resulting α-silylated ketone **17b** partially decomposed on silica and was isolated in only 30% yield after column chromatography. The ^{1}H and ^{13}C NMR spectra of **17a**,**b** clearly indicated the presence of the untouched diene moieties. The coupling constant $J_{H1,H8}$ (8 Hz) indicated the *cis* configuration of H1 and H8, and as a consequence, the *endo* position of the phenyl (or trimethylsilyl) group. Thus, ketones **17a**,**b** formally result from the concerted 1,2-migration of the phenyl (respectively trimethylsilyl) substituent (Scheme 9).[14]

Strikingly, whatever option we chose for the electrophilic activation of **1a**−**c** (see Scheme 4 for an overview), we obtained 1,5,9-substituted tricyclo[4.2.1.0^{2,8}]non-3-enes of type **IV** as single isomers. Some aspects of this high regio- and stereoselectivity can be easily rationalized. First, as shown in Scheme 10, two regioisomers **IV** and **IV′** could be formed in principle. However, the latter can be reasonably excluded because of unfavorable steric interactions with R substituents. Second, the stereoselectivity at C9 is clearly related to the attack of the less hindered *exo* face of **1a**−**c** by electrophiles.

SCHEME 10. Stereo- and Regioselectivity for R and E Substituents



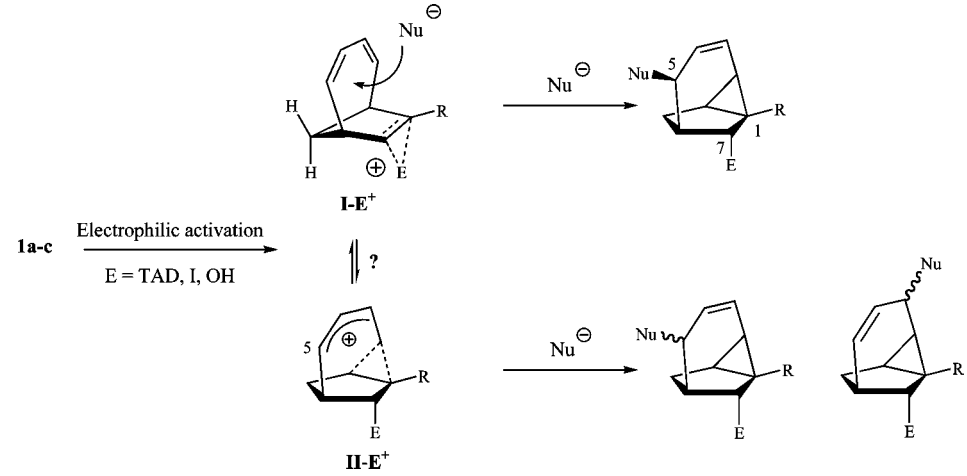
The origin of the stereoselectivity at C5 addresses the issue of the nature of the intermediate which was formed upon the electrophilic activation of **1a**−**c**. On one hand, addition of halonium reactants[15] or triazolinediones[12] on olefins and protonation of epoxides are known to yield bridged cations. Thus, the electrophilic activation of **1a**−**c** could result in the formation of the bridged cation **I-E**$^+$ (Scheme 11). On the other hand, the parent cation **II** (R = E = H) adopts a tricyclo[4.2.1.0^{2,8}]-non-3-enoid structure, which involves the homoconjugation of the diene.[7] Thus, the formation of the related allylic cation **II-E**$^+$ has to be considered as well. However, this latter does not account for the observed high stereoselectivity. Indeed, the two faces of the allylic moiety of **II-E**$^+$ have a similar steric environment. In the case of the parent cation **II** (R = E = H), these two faces are even strictly equivalent and cannot be distinguished by a nonchiral nucleophile. In the case of cation **II-E**$^+$, the way that various remote substituents, R or E, could selectively control this attack on C5 is difficult to understand.

For this reason, we postulate that the nucleophilic attack occurred on bridged cations **I-E**$^+$ and was concerted with the formation of the tricyclo[4.2.1.0^{2,8}]non-3-enoid structure. As shown in Scheme 12, an early transition state could account for the observed diasteroselectivity at C5. In particular, in addition to the main interaction between the HOMO of the nucleophile and the π^* system of the activated diene, a stabilizing secondary interaction between the HOMO of the

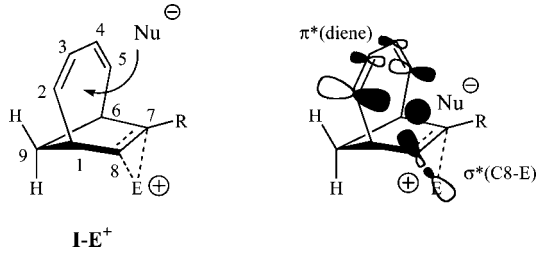
(14) (a) Fleming, I.; Newton, T. W. *J. Chem. Soc., Perkin Trans. 1* **1984**, 119–123. (b) Burford, C.; Cooke, F.; Roy, G.; Magnus, P. *Tetrahedron* **1983**, *39*, 867–876. (c) Ooi, T.; Maruoka, K. *Chem. Lett.* **1997**, 519–520.

(15) Brown, R. S.; Nagorski, R. W.; Bennet, A.; MacClung, R. E. D.; Aarts, G. H. M.; Klobukowski, M.; MacDonald, R.; Santarsiero, B. D. *J. Am. Chem. Soc.* **1994**, *116*, 2448–2456.

SCHEME 11. Structure of the Cationic Intermediate: I-E$^+$ or II-E$^+$?



SCHEME 12. HOMO−π* and HOMO−σ^*_{CE} Interactions in the Postulated Early Transition State for the Concerted Nucleophilic Attacks on Intermediate I-E$^+$



nucleophile and the empty low-lying $\sigma^*_{C8\text{-}E}$, which is related to the weak C8-E bond, could explain both the regio- and stereoselectivity of the attack of the nucleophile.

Conclusion

In summary, the electrophilic activation of readily available 7-substituted bicyclo[4.2.1]nonatrienes and the in situ trapping by water or alcohols led to the regio- and diastereoselective formation of original 1,5,9-trisubstituted tricyclo[4.2.1.0^{2,8}]non-3-enes. Several electrophilic reactants were successfully tested: 4-isopropyl-1,2,4-triazolinedione, *N*-iodosuccinimide, or an epoxidation/acidic ring-opening sequence. Sometimes, they appeared to be complementary: whereas the latter was efficient for phenyl- or alkyl- substituted substrates **1a**,**c**, *N*-iodosuccinimide was more suitable for the silylated derivative **1b**.

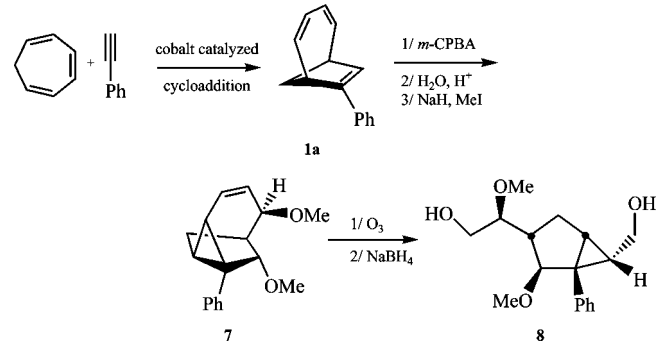
The synthesis of **8** from cheap commercial products, namely cycloheptatriene and phenylacetylene, illustrates the potentiality of these new synthons (Scheme 13). This fused cyclopropane, which features six controlled stereocenters, was obtained in 33% yield in only four steps, a cobalt-catalyzed cycloaddition, an epoxidation/hydrolysis sequence, the protection of a diol, and a reductive ozonolysis. Of note, in principle, the first step can be performed enantioselectively with up to 90% ee.[5b]

Further studies are now underway to extend the scope of that methodology, to develop its applications in organic synthesis, and to study its mechanism, with a particular focus on the origin of the remarkable diastereoselectivity of the nucleophilic attack step.

Experimental Section

1-(5-Ethoxy-1-phenyltricyclo[4.2.1.0^{2,8}]non-3-ene-9-yl)-4-isopropyl-1,2,4-triazolidinedione 2. 4-Isopropyl-1,2,4-triazolinedi-

SCHEME 13. Synthesis of Fused Cyclopropane 8



one[11] (216 mg; 1.53 mmol; 3 equiv) was added at room temperature to a solution of **1a** (100 mg; 0.51 mmol; 1 equiv) in chloroform (5 mL). After stirring 5 min., ethanol (1 mL) was added and the mixture was warmed at 40 °C for 24 h. After cooling down to room temperature, the solution was concentrated. Purification by column chromatography on silica gel (dichloromethane/acetone: 95/5) afforded **2** as a white crystalline solid. 194 mg; 99% yield; mp: 203 °C. ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.24−1.33 (m, 9H), 1.45 (d, J = 12 Hz, 1H), 1.57 (pseudo t, J = 8.3 Hz, 1H), 2.55−2.78 (m, 3H), 3.40−3.69 (m, 2H), 3.72−3.77 (m, 1H), 4.03−4.24 (m, 1H), 5.01 (s, 1H), 5.62 (ddd, J = 2.1, 3.3, 11.7 Hz, 1H), 5.94 (ddd, J = 1.3, 8.2, 11.7 Hz, 1H), 7.19−7.34 (m, 5H), 7.49 (s, 1H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 15.5 (s, CH_3), 19.3 (s, CH_3), 19.4 (s, CH_3), 26.6 (s, CH_2), 28.9 (s, CH), 31.0 (s, CH), 43.9 (s, CH), 44.2 (s, CH), 45.6 (s, C), 59.7 (s, CH), 63.9 (s, CH_2), 77.9 (s, CH), 124.6 (s, CH), 126.1 (s, CH), 126.7 (s, CH), 128.1 (s, CH), 128.5 (s, CH), 139.0 (s, C), 152.7 (s, C), 155.4 (s, C). HRMS (ESI-MS) [M-EtO]$^+$: found 336.1705; calculated for $C_{20}H_{22}N_3O_2$: 336.1707.

Synthesis of 5,9-dimethoxy-1-trimethylsilyltricyclo[4.2.1.0^{2,8}]non-3-enes 3 and 4. At 0 °C and under nitrogen atmosphere, *N*-iodosuccinimide (403 mg; 1.79 mmol; 1.7 equiv) was added to a solution of **1b** (200 mg; 1.05 mmol; 1 equiv) in methanol (10 mL). The reaction mixture was stirred in the dark at 0 °C. After 4 h, the reaction was quenched with a 20% aqueous solution of $Na_2S_2O_3$ (7 mL), and the mixture was stirred overnight at 0 °C. After addition of chloroform (20 mL), the two layers were separated and the aqueous one was extracted with chloroform (3 × 20 mL). The combined organic solutions were dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel (petroleum ether/diethyl ether: 95/5) afforded **3** and **4**.

3: glassy oil; 89 mg; 33% yield; R_f 0.48 (petroleum ether/diethyl ether: 95/5); ^{1}H NMR (200 MHz, $CDCl_3$) δ −0.02 (s, 9H), 1.24−1.41 (m, 2H), 1.73 (dd, J = 4.0, 7.6 Hz, 1H), 2.29 (dddd, J = 1.0, 4.0, 10.5, 13.5 Hz, 1H), 2.57 (dtm, J = 3.1, 10.3 Hz, 1H),

3.27 (s, 3H), 3.41 (s, 3H), 3.48 (s, 1H), 3.48−3.52 (m, 1H), 5.40 (dt, J = 2.9, 11.8 Hz, 1H), 5.79 (ddd, J = 1.7, 8.3, 11.8 Hz, 1H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ −1.7 (s, CH_3), 22.1 (s, CH), 27.5 (s, CH_2), 29.9 (s, CH), 33.5 (s, C), 44.1 (s, CH), 56.3 (s, CH_3), 56.7 (s, CH_3), 80.3 (s, CH), 86.9 (s, CH), 124.8 (s, CH), 126.8 (s, CH); HRMS (ESI-MS) $[M + NH_4]^+$ found 270.1891, calcd for $C_{14}H_{28}NO_2Si$ 270.1883.

4: glassy oil; 32 mg; 12% yield; R_f 0.38 (petroleum ether/diethyl ether 95/5); ^{1}H NMR (200 MHz, $CDCl_3$) δ −0.01 (s, 9H), 1.28 (t, J = 7.7 Hz, 1H), 1.75 (dd, J = 3.9, 7.5 Hz, 1H), 1.95−2.12 (m, 2H), 2.59−2.65 (m, 1H), 3.28 (s, 3H), 3.36 (s, 3H), 3.40 (d, J = 2.4 Hz, 1H), 3.71−3.76 (m, 1H), 5.42 (dt, J = 2.8, 11.8 Hz, 1H), 5.80 (ddd, J = 1.4, 8.3, 11.8 Hz, 1H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ −1.6 (s, CH_3), 22.1 (s, CH), 26.0 (s, CH_2), 27.8 (s, C), 33.3 (s, CH), 44.7 (s, CH), 55.9 (s, CH_3), 56.7 (s, CH_3), 80.9 (s, CH), 89.1 (s, CH), 124.5 (s, CH), 127.7 (s, CH); HRMS (ESI-MS) $[M + Na]^+$ found 275.1436, calcd for $C_{14}H_{24}NaO_2Si$ 275.1437.

Synthesis of Epoxides 5a and 5c. At 0 °C, a solution of *m*-CPBA (121 mg; 0.70 mmol; 1.3 equiv) in chloroform (2 mL) was added to a mixture of cycloadduct **1a**,**c** (1.0 equiv) and $NaHCO_3$ (59 mg; 0.70 mmol; 1.3 equiv) in chloroform (6 mL). The mixture was stirred for 10 min at 0 °C, and the reaction was quenched with 1 M NaOH (2 mL). After being stirred for 15 min at 0 °C, the two layers were separated. The organic layer was washed with 1 M NaOH (2 mL) and brine (2 × 3 mL), dried over Na_2SO_4, and filtered. Removal of solvent under vacuum gave compounds **5a**,**c**.

7,8-Epoxy-7-phenylbicyclo[4.2.1]nona-2,4-diene 5a: colorless oil; 331 mg; 75% yield; R_f 0.58 (petroleum ether); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.60 (d, J = 12 Hz, 1H), 2.25−2.38 (m, 1H), 3.11 (t, J = 6.7 Hz, 1H), 3.22 (t, J = 7.2 Hz, 1H), 3.73 (s, 1H), 5.70−6.03 (m, 4H), 7.27−7.41 (m, 5H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 25.4 (s, CH_2), 40.0 (s, CH), 41.6 (s, CH), 65.3 (s, CH), 70.1 (s, C), 125.6 (s, CH), 127.0 (s, CH), 128.1 (s, CH), 128.2 (s, CH), 132.4 (s, CH), 134.6 (s, CH), 135.7 (s, C); HRMS (ESI-MS) $[M + H]^+$ found 211.1120, calcd for $C_{15}H_{15}O$ 211.1117.

7,8-Epoxy-7-butylbicyclo[4.2.1]nona-2,4-diene 5c: colorless oil; 99 mg; 97% yield; R_f 0.72 (petroleum ether/diethyl ether 90/10); ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.89 (t, J = 6.9 Hz, 3H), 1.41 (d, J = 12 Hz, 1H), 1.30−1.57 (m, 5H), 2.06−2.16 (m, 2H), 2.80 (t, J = 7.0 Hz, 1H), 2.93 (t, J = 6.4 Hz, 1H), 3.19 (s, 1H), 5.73−6.03 (m, 4H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 14.0 (s, CH_3), 22.9 (s, CH_2), 24.8 (s, CH_2), 27.6 (s, CH_2), 28.7 (s, CH_2), 39.7 (s, CH), 40.9 (s, CH), 64.7 (s, CH), 70.5 (s, C), 125.5 (s, CH), 126.6 (s, CH), 132.8 (s, CH), 134.7 (s, CH);HRMS (ESI-MS) $[M + H]^+$ found 191.1430, calcd for $C_{13}H_{19}O$ 191.1430.

Synthesis of 7,8-Epoxy-7-trimethylsilylbicyclo[4.2.1]nona-2,4-diene 5b. At 0 °C, a solution of *m*-CPBA (118 mg; 0.68 mmol; 1.3 equiv) in toluene (2 mL) was added dropwise to a solution of **1b** (100 mg; 0.52 mmol; 1 equiv) and $NaHCO_3$ (58 mg; 0.68 mmol; 1.3 equiv) in toluene (1 mL). The mixture was stirred for 30 min at 0 °C, and the reaction was quenched with 1 M NaOH (2 mL). After being stirred for 15 min at 0 °C, the two layers were separated. The organic one was washed with 1 M NaOH (2 mL) and brine (2 × 2 mL), dried over Na_2SO_4, and filtered. Removal of the solvent afforded a mixture of of **5b** and **11/12**. Purification by column chromatography on silica gel deactivated by Et_3N (petroleum ether/diethyl ether 98/2) afforded **5b** as a colorless oil: 54 mg; 60% yield; R_f 0.72 (petroleum ether/diethyl ether 98/2); ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.07 (s, 9H), 1.44 (d, J = 12.0 Hz, 1H), 2.03−2.15 (m, 1H), 2.90 (dd, J = 6.5, 7.6 Hz, 1H), 3.01 (t, J = 6.6 Hz, 1H), 3.28 (s, 1H), 5.66−5.81 (m, 2H), 5.83−5.96 (m, 2H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ −2.1 (s, CH_3), 24.2 (s, CH_2), 40.4 (s, CH), 42.2 (s, CH), 63.4 (s, CH), 126.4 (s, CH), 126.5 (s, CH), 133.4 (s, CH), 134.6 (s, CH), a quaternary carbon was not detected; HRMS (ESI-MS) $[M + K]^+$ found 245.0761, calcd for $C_{12}H_{18}KOSi$ 245.0758.

Synthesis of Diols 6a and 6c. $NaIO_4$ (462 mg; 2.16 mmol; 1.7 equiv) was added to a solution of epoxide **5a** (respectively **5c**) (267 mg; 1.27 mmol; 1 equiv) in THF (8 mL) and water (4 mL). After the solution was stirred for 1 night at room temperature, water (20 mL) was added. The product was extracted with dichloromethane (4 × 10 mL). Combined organic solutions were washed with brine (2 × 5 mL), dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel (petroleum ether/ethyl acetate: 40/60 + 1% H_2O) afforded **6a** (respectively **6c**).

5,9-Dihydroxy-1-phenyltricyclo[4.2.1.0^{2,8}]non-3-ene 6a: colorless oil; 223 mg; 77% yield; R_f 0.19 (petroleum ether/ethyl acetate 40/60); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.53 (d, J = 12.3 Hz, 1H), 1.57 (t, J = 8.3 Hz, 1H), 2.31 (dd, J = 3.3, 8.0 Hz, 1H), 2.57−2.63 (m, 2H), 4.14−4.17 (m, 1H), 4.43 (s, 1H), 5.51 (ddd, J = 2.1, 3.2, 11.6 Hz, 1H), 5.89 (ddd, J = 1.5, 8.2, 11.6 Hz, 1H), 7.21−7.34 (m, 5H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 26.3 (s, CH_2), 28.6 (s, CH), 30.4 (s, CH), 48.6 (s, C), 50.9 (s, CH), 70.5 (s, CH), 74.1 (s, CH), 124.7 (s, CH), 126.5 (s, CH), 127.2 (s, CH), 128.3 (s, CH), 128.7 (s, CH), 140.1 (s, C); HRMS (ESI-MS) $[M + NH_4]^+$ found 246.1486, calcd for $C_{15}H_{20}NO_2$ 246.1488.

1-Butyl-5,9-dihydroxytricyclo[4.2.1.0^{2,8}]non-3-ene 6c: red oil; 51 mg; 66% yield; R_f 0.25 (petroleum ether/ethyl acetate 40/60); ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.90 (t, J = 6.5 Hz, 3H), 1.21−1.44 (m, 5H), 1.59−1.70 (m, 5H), 2.05−2.21 (m, 1H), 2.30−2.41 (m, 1H), 4.02−4.08 (m, 1H), 5.38 (ddd, J = 1.9, 3.3, 11.6 Hz, 1H), 5.85 (ddd, J = 1.5, 8.3, 11.6 Hz, 1H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 14.2 (s, CH_3), 22.9 (s, CH_2), 25.1 (s, CH), 26.1 (s, CH_2), 29.8 (s, CH_2), 31.3 (s, CH), 31.6 (s, CH_2), 44.1 (s, C), 52.0 (s, CH), 70.9 (s, CH), 73.3 (s, CH), 125.9 (s, CH), 126.4 (s, CH); HRMS (ESI-MS) $[M + Na]^+$ found 231.1347, calcd for $C_{13}H_{20}O_2Na$ 231.1355.

5,9-Dimethoxy-1-phenyltricyclo[4.2.1.0^{2,8}]non-3-ene 7. At 0 °C, a solution of **6a** (400 mg; 1.75 mmol; 1 equiv) in THF (10 mL) was added to a suspension of sodium hydride (93 mg; 3.88 mmol; 2.2 equiv) in THF (5 mL). The mixture was stirred for 30 min at 0 °C and for an additional 1 h at room temperature. Then iodomethane (1.24 g; 8.76 mmol; 5 equiv) was added, and the mixture was stirred at room temperature for 16 h. The reaction was quenched with water (10 mL) at 0 °C. After the mixture was stirred for 2 h at room temperature, diethyl ether (25 mL) was added, and the two layers were separated. The aqueous layer was extracted with diethyl ether (3 × 15 mL) and the combined organic solutions were dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel (petroleum ether/diethyl ether 90/10) afforded **7** as a colorless oil: 327 mg; 73% yield. R_f 0.70 (petroleum ether/diethyl ether 90/10); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.40 (d, J = 13.3 Hz, 1H), 1.52 (t, J = 8.1 Hz, 1H), 2.39 (dd, J = 4.0, 8.2 Hz, 1H), 2.54 (dddd, J = 0.8, 4.1, 10.2, 13.3 Hz, 1H), 2.79 (ddd, J = 2.3, 4.4, 10.1 Hz, 1H), 3.19 (s, 3H), 3.47 (s, 3H), 3.58 (m, 1H), 3.93 (s, 1H), 5.55 (dt, J = 2.9, 11.7 Hz, 1H), 5.90 (ddd, J = 1.6, 8.2, 11.7 Hz, 1H), 7.14−7.33 (m, 5H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 26.4 (s, CH_2), 29.5 (s, CH), 30.9 (s, CH), 43.6 (s, CH), 47.4 (s, C), 56.68 (s, CH_3), 56.70 (s, CH_3), 79.8 (s, CH), 83.8 (s, CH), 125.1 (s, CH), 125.4 (s, CH), 125.8 (s, CH), 127.96 (s, CH), 128.03 (s, CH), 141.1 (s, C); HRMS (ESI-MS) $[M + NH_4]^+$ found 274.1795, calcd for $C_{17}H_{24}NO_2$ 274.1801.

2-((1*R,2*S**,3*R**,5*R**,6*S**)-6-Hydroxymethyl-2-methoxy-1-phenylbicyclo[3.1.0]hex-3-yl)-2*S**-methoxyethanol 8.** Ozone was passed through a solution of **6a** (200 mg; 0.78 mmol; 1 equiv) in a mixture of dichloromethane (16 mL) and methanol (8 mL) in the presence of red Congo until a yellow coloration appeared (∼15 min). The reaction was quenched with a solution of sodium borohydride (89 mg; 2.34 mmol; 3 equiv) in ethanol (20 mL). After being stirred for 1 h, the mixture was filtered over a short pad of silica gel using dichloromethane as eluent. After removal of the solvent, the product was dissolved in water (10 mL), and this aqueous phase was extracted with dichloromethane (4 × 10 mL). The combined organic solutions were washed with brine (10 mL), dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel (diethyl ether) afforded **8** as

a viscous colorless oil: 189 mg; 83% yield; R_f 0.43 (diethyl ether); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.32−1.47 (m, 2H), 1.72−1.85 (m, 2H), 2.24−2.35 (m, 1H), 2.41 (broad s, 2H), 2.83 (s, 3H), 3.25 (dt, J = 3.6, 7.3 Hz, 1H), 3.45 (s, 3H), 3.49 (d, J = 9.0 Hz, 1H), 3.56 (dd, J = 4.1, 12.3 Hz, 1H), 3.78 (dd, J = 3.4, 12.3 Hz, 1H), 3.82−3.98 (m, 2H), 7.15−7.54 (m, 5H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 23.8 (s, CH_2), 29.9 (s, CH), 30.2 (s, CH), 30.8 (s, CH), 41.2 (s, C), 57.3 (s, CH_2), 57.9 (s, CH_3), 58.1 (s, CH_3), 62.3 (s, CH_2), 82.5 (s, CH), 84.8 (s, CH), 126.4 (s, CH), 127.5 (s, CH), 131.1 (s, CH), 140.5 (s, C); HRMS (ESI-MS) $[M + Na]^+$ found 315.1565, calcd for $C_{17}H_{24}NaO_4$ 315.1566.

9-Hydroxy-1-phenyltricyclo[4.2.1.0^{2,8}]non-3-ene-5-one 9. Compound **6a** (277 mg; 1.21 mmol; 1 equiv) was diluted in dichloromethane (15 mL) and added to a mixture of pyridinium dichromate (1.14 g; 3.03 mmol; 2.5 equiv), sodium acetate (179 mg; 2.18 mmol; 1.8 equiv), Celite (2.8 g), and dichloromethane (5 mL) at 0 °C. After 2 h at room temperature, diethyl ether (20 mL) was added, and the mixture was filtered over silica and Celite. Solids were washed with diethyl ether (2 × 10 mL). The combined organic solutions were dried over $MgSO_4$, filtered, and concentrated. Purification by column chromatography on silica gel (petroleum ether/ethyl acetate 70/30) afforded **9** as a white solid: 204 mg; 74% yield; mp 139 °C; R_f 0.20 (petroleum ether/ethyl acetate 70/30); ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.70 (d, J = 14 Hz, 1H), 1.98 (t, J = 8.3 Hz, 1H), 2.11 (broad s, 1H), 2.55 (dd, J = 3.2, 8.0 Hz, 1H), 2.74−2.87 (m, 1H), 3.05 (dd, J = 2.2, 9.0 Hz, 1H), 4.21 (d, J = 3 Hz, 1H), 5.96 (dd, J = 2.2, 11.7 Hz, 1H), 6.95 (dd, J = 9.0, 11.7 Hz, 1H), 7.18−7.38 (m, 5H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 25.4 (s, CH_2), 30.7 (s, CH), 31.5 (s, CH), 46.3 (s, C), 59.3 (s, CH), 74.8 (s, CH), 127.4 (s, CH), 127.7 (s, CH), 128.7 (s, CH), 128.9 (s, CH), 138.1 (s, C), 145.3 (s, CH), 200.5 (s, C═O); IR 1651 cm^{-1} (ν_{CO}); HRMS (ESI-MS) $[M + H]^+$ found 227.1062, calcd for $C_{15}H_{15}O_2$ 227.1066.

1-Phenyltricyclo[4.2.1.0^{2,8}]non-3-ene-5,9-dione 10. Compound **6a** (60 mg; 0.27 mmol; 1 equiv) was diluted in dichloromethane (1.5 mL) and added to a mixture of pyridinium dichromate (400 mg; 1.06 mmol; 3.9 equiv), sodium acetate (62 mg; 0.76 mmol; 2.8 equiv), Celite (1 g), and dichloromethane (3.5 mL) at 0 °C. After 48 h at room temperature, diethyl ether (5 mL) was added, and the mixture was filtered over silica and Celite. Solids were washed with diethyl ether (2 × 5 mL). The combined organic solutions were dried over $MgSO_4$, filtered and concentrated. Purification by column chromatography on silica gel (petroleum ether/ethyl acetate 75/25) afforded **10** as white crystalline solid: 57 mg; 96% yield; mp = 115 °C; ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.10 (d, J = 4.2 Hz, 1H), 2.47 (t, J = 8.4 Hz, 1H), 2.87 (dddd, J = 0.8, 4.0, 9.4, 14.2 Hz, 1H), 3.12 (dd, J = 4.0, 8.0 Hz, 1H), 3.36 (dd, J = 2.0, 9.2 Hz, 1H), 5.93 (ddd, J = 0.3, 2.4, 11.8 Hz, 1H), 7.01 (dd, J = 8.7, 11.9 Hz, 1H), 7.21−7.34 (m, 5H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 22.9 (s, CH_2), 31.4 (s, CH), 36.5 (s, CH), 44.8 (s, C), 61.1 (s, CH), 127.6 (s, CH), 127.9 (s, CH), 128.5 (s, CH), 128.8 (s, CH), 133.6 (s, C), 144.2 (s, CH), 191.6 (s, C═O), 204.3 (s, C═O); IR 1724, 1669 cm^{-1} (ν_{CO}); HRMS (ESI-MS) $[M + H]^+$ found 225.0916, calcd for $C_{15}H_{13}O_2$ 225.0910.

Mixture of 2,3-Epoxy-7/8-trimethylsilylbicyclo[4.2.1]nona-4,7-dienes 11 and 12. At 6 °C, a solution of Oxone (2.66 g; 8.66 mmol of potassium peroxomonosulfate, 3.3 equiv) in water (16 mL) was added dropwise to a well-stirred biphasic mixture of benzene (25 mL) and buffered water (10 mL; pH 7.5; 0.05 M phosphate buffer) containing **1b** (500 mg; 2.63 mmol; 1 equiv), 18-crown-6 (139 mg; 0.53 mmol; 0.20 equiv), and acetone (2.1 mL). During the addition, pH was kept constant by careful addition of 0.5 M KOH. Then, the mixture was allowed to stand at 10 °C maintaining pH = 7.5. When no starting material was detected by TLC analysis (petroleum ether/ diethyl ether 90/10), the two layers were separated and the aqueous one was extracted with dichloromethane (3 × 20 mL). The combined organic solutions were dried over Na_2SO_4 and filtered. Removal of the solvent afforded a mixture of **11** and **12**: 531 mg; 98% yield; R_f 0.71/0.74 (petroleum ether/ diethyl ether 90/10); HRMS (ESI-MS) $[M + H]^+$ found 207.1196, calcd for $C_{12}H_{19}OSi$ 207.1199.

11: ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.06 (s, 9H), 1.87−1.93 (m, 2H), 3.04−3.16 (m, 2H), 3.34−3.44 (m, 2H), 5.70 (dd, J = 5.2, 9.3 Hz, 1H), 6.10−6.29 (m, 2H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ −1.3 (s, CH_3), 37.8 (s, CH_2), 45.6 (s, CH), 47.9 (s, CH), 52.0 (s, CH), 61.4 (s, CH), 124.2 (s, CH), 140.2 (s, CH), 144.4 (s, CH), 145.4 (s, C).

12: ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.12 (s, 9H), 1.87−1.93 (m, 2H), 3.04−3.16 (m, 2H), 3.34−3.44 (m, 2H), 5.65 (dd, J = 5.2, 9.4 Hz, 1H), 6.10−6.29 (m, 2H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ −1.2 (s, CH_3), 37.9 (s, CH_2), 46.4 (s, CH), 47.2 (s, CH), 52.0 (s, CH), 61.8 (s, CH), 124.9 (s, CH), 143.1 (s, CH), 146.1 (s, CH), 152.2 (s, C).

9-Hydroxy-1-phenyltricyclo[4.2.1.0^{2,8}]non-3-en-5-yl Benzoate 13. At 0 °C, benzoic acid (116 mg; 0.95 mmol; 1 equiv) was added to a solution of **5a** (200 mg; 0.95 mmol; 1 equiv) and $NaHCO_3$ (80 mg; 0.95 mmol; 1 equiv) in chloroform (5 mL). The mixture was stirred for 76 h at room temperature. Then chloroform (5 mL) was added, and the reaction was quenched with 1 M NaOH (10 mL). After being stirred for 15 min, the two layers were separated, and the organic one was washed with 1 M NaOH (10 mL) and brine (3 × 10 mL), dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel (petroleum ether/diethyl ether 80/20) afforded **13** as a colorless oil: 92 mg; 29% yield; ^{1}H NMR (200 MHz, $CDCl_3$) δ 1.62−1.69 (m, 2H), 2.38 (dd, J = 3.9, 8.2 Hz, 1H), 2.66−2.74 (m, 1H), 2.80 (ddd, J = 2.2, 4.6, 10.1 Hz, 1H), 4.60 (s, 1H), 5.48−5.51 (m, 1H), 5.58 (ddd, J = 2.3, 3.5, 11.6 Hz, 1H), 6.05 (ddd, J = 1.5, 8.3, 11.6 Hz, 1H), 7.32−7.61 (m, 8H), 8.06−8.09 (m, 2H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 26.5 (s, CH_2), 28.5 (s, CH), 30.4 (s, CH), 47.8 (s, CH), 49.2 (s, C), 73.1 (s, CH), 75.3 (s, CH), 123.7 (s, CH), 127.1 (s, CH), 127.5 (s, CH), 128.3 (s, CH), 128.7 (s, CH), 128.9 (s, CH), 129.7 (s, CH), 130.5 (s, C), 132.9 (s, CH), 139.5 (s, C), 165.8 (s, C═O); HRMS (ESI-MS) $[M + NH_4]^+$ found 350.1755, calcd for $C_{22}H_{24}NO_3$ 350.1751.

Synthesis of 14 and 16. At 0 °C, a solution of *m*-CPBA (920 mg; 5.33 mmol; 1.1 equiv) in chloroform (7 mL) was added dropwise to a solution of **5a** (907 mg; 4.68 mmol; 1 equiv) and $NaHCO_3$ (391 mg; 4.65 mmol; 1 equiv) in chloroform (18 mL). The mixture was stirred for 2 h at 0 °C and for 76 h at room temperature. Then, the mixture was washed with 1 M NaOH (2 × 10 mL) and brine (3 × 10 mL), dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel deactivated by Et_3N (petroleum ether/diethyl ether 90/10) afforded **14** and **16**.

9-Hydroxy-1-phenyltricyclo[4.2.1.0^{2,8}]non-3-en-5-yl *m*-chlorobenzoate 14: white solid; 460 mg; 27% yield; mp 103 °C; R_f 0.05 (petroleum ether/diethyl ether 90/10); ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.47 (d, J = 2.7 Hz, 1H, O*H*), 1.64 (d, J = 13.3 Hz, 1H), 1.67 (t, J = 8.2 Hz, 1 Hz), 2.38 (dd, J = 3.8, 8.2 Hz, 1H), 2.66−2.82 (m, 2H), 4.57 (d, J = 2.3 Hz, 1H), 5.48−5.59 (m, 2H), 6.07 (ddd, J = 1.4, 8.4, 11.6 Hz, 1H), 7.28−7.41 (m, 6H), 7.53 (ddd, J = 1.1, 2.2, 8.0 Hz, 1H), 7.96 (dt, J = 1.4, 7.8 Hz, 1H), 8.03 (t, J = 1.8 Hz, 1H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 26.4 (s, CH_2), 28.2 (s, CH), 30.5 (s, CH), 47.6 (s, CH), 49.1 (s, C), 73.6 (s, CH), 75.0 (s, CH), 123.1 (s, CH), 126.9 (s, CH), 127.77 (s, CH), 127.83 (s, CH), 128.5 (s, CH), 128.8 (s, CH), 129.55 (s, CH), 129.57 (s, CH), 132.1 (s, C), 132.9 (s, CH), 134.3 (s, C), 139.3 (s, C), 164.4 (s, C═O); HRMS (ESI-MS) $[M + NH_4]^+$: found 384.1360, calcd for $C_{22}H_{23}ClNO_3$ 384.1360.

8-Hydroxy-7-phenylbicyclo[4.2.1]nona-2,4-dien-7-yl *m*-chlorobenzoate 16: glassy oil; 450 mg; 26% yield; R_f 0.11 (petroleum ether/diethyl ether 90/10); ^{1}H NMR (300 MHz, $CDCl_3$) δ 1.84 (d, J = 11.4 Hz, 1H), 2.75−2.82 (m, 1H), 3.08−3.20 (m, 2H), 5.33 (dd, J = 7.5, 11.3 Hz, 1H), 5.76 (d, J = 2.7 Hz, 1H), 5.78−5.91 (m, 2H), 6.56 (t, J = 9.4 Hz, 1H), 7.30−7.40 (m, 4H), 7.49−7.55 (m, 3H), 7.88 (d, J = 7.7 Hz, 1H), 7.96 (s, 1H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 29.2 (s, CH_2), 43.5 (s, CH), 51.2 (s, CH), 84.3

(s, CH), 93.7 (s, C), 123.6 (s, CH), 126.1 (s, CH), 126.7 (s, CH), 127.7 (s, CH), 128.0 (s, CH), 128.2 (s, CH), 129.5 (s, CH), 129.6 (s, CH), 131.3 (s, C), 131.9 (s, CH), 133.1 (s, CH), 134.4 (s, C), 139.4 (s, CH), 139.6 (s, C), 164.3 (s, C═O); HRMS (ESI-MS) $[M + NH_4]^+$ found 384.1358, calcd for $C_{22}H_{23}ClNO_3$ 384.1360.

Synthesis of 9-Hydroxy-1-trimethylsilyltricyclo[4.2.1.0^{2,8}]non-3-en-5-yl *m*-Chlorobenzoate 15. At 30 °C, a solution of *m*-CPBA (1.229 g; 7.12 mmol; 1 equiv) in chloroform (11 mL) was added dropwise to a solution of **5b** (1.354 g; 7.12 mmol, 1 equiv) in chloroform (1 mL). The mixture was stirred for 16 h at 30 °C. After filtration on Büchner, the organic solution was washed with 1 M NaOH (2 × 10 mL), dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel (petroleum ether/diethyl ether 90/10) afforded **15** as a white solid: 309 mg; 12% yield; mp 108 °C; R_f 0.27 (petroleum ether/diethyl ether 90/10); ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.08 (s, 9H), 1.40 (t, J = 7.9 Hz, 1H), 1.62 (d, J = 12.9 Hz, 1H), 1.85 (dd, J = 3.6, 7.6 Hz, 1H), 2.30−2.62 (m, 2H), 4.28 (s, 1H), 5.36−5.45 (m, 2H), 5.96 (ddd, J = 2.5, 8.4, 12.6 Hz, 1H), 7.37 (t, J = 7.8 Hz, 1H), 7.53 (ddd, J = 1.2, 2.1, 8.0 Hz, 1H), 7.93 (dt, J = 1.4, 7.7 Hz, 1H), 8.00 (t, J = 1.7 Hz, 1H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ −1.4 (s, CH_3), 22.1 (s, CH), 27.2 (s, CH_2), 30.1 (s, CH), 34.5 (s, C), 50.7 (s, CH), 74.2 (s, CH), 77.8 (s, CH), 122.6 (s, CH), 127.8 (s, CH), 129.3 (s, CH), 129.7 (s, CH), 132.2 (s, C), 133.0 (s, CH), 134.5 (s, C), 164.6 (s, C═O); HRMS (ESI-MS) $[M + NH_4]^+$ found 380.1439, calcd for $C_{19}H_{27}ClNO_3Si$ 380.1443.

Synthesis of 8-Phenylbicyclo[4.2.1]nona-2,4-diene-7-one 17a. At room temperature, $BF_3 \cdot OEt_2$ (129 μL; 1.05 mmol; 1.1 equiv) was added dropwise to a solution of **5a** (200 mg; 0.95 mmol; 1 equiv) in chloroform (2 mL). After being stirred for 12 h at room temperature, the reaction was quenched with water (1 mL) and stirred for an additional 2 h. Water (5 mL) and dichloromethane (5 mL) were added, and the two layers were separated. The aqueous layer was extracted with dichloromethane (3 × 10 mL), and the combined organic solutions were dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel (petroleum ether/diethyl ether 80/20) afforded **17a** as a colorless oil: 50 mg; 25% yield; R_f 0.27 (petroleum ether/diethyl ether 80/20); ^{1}H NMR (200 MHz, $CDCl_3$) δ 2.08 (d, J = 12.6 Hz, 1H), 2.56−2.65 (m, 1H), 3.37−3.45 (m, 1H), 3.55 (t, J = 7.9 Hz, 1H), 3.94 (d, J = 8.4 Hz, 1H), 5.60 (dd, J = 7.9, 11.5 Hz, 1H), 5.82 (ddd, J = 1.1, 7.1, 11.6 Hz, 1H), 5.98−6.14 (m, 2H), 7.10−7.13 (m, 2H), 7.23−7.34 (m, 3H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ 27.8 (s, CH_2), 43.0 (s, CH), 49.4 (s, CH), 69.8 (s, CH), 125.6 (s, CH), 127.0 (s, CH), 127.1 (s, CH), 128.1 (s, CH), 129.8 (s, CH), 131.0 (s, CH), 134.0 (s, C), 135.3 (s, CH), 212.5 (s, C═O); HRMS (ESI-MS) $[M + H]^+$ found 211.1116, calcd for $C_{15}H_{15}O$ 211.1117.

Synthesis of 8-Trimethylsilylbicyclo[4.2.1]nona-2,4-diene-7-one 17b. At −78 °C, $BF_3 \cdot OEt_2$ (14 μL; 0.11 mmol; 0.24 equiv) was added dropwise to a solution of **5b** (100 mg; 0.48 mmol; 1 equiv) in dichloromethane (1 mL). After being stirred 30 min at −78 °C, the reaction was quenched with a saturated aqueous solution of $NaHCO_3$ (0.5 mL), and the mixture was slowly warmed up to room temperature. The two layers were separated, and the organic one was washed with brine (3 × 1 mL), dried over Na_2SO_4, filtered, and concentrated. Purification by column chromatography on silica gel (petroleum ether/ethyl acetate 95/5) afforded **17b** as a colorless oil: 30 mg; 30% yield; R_f 0.30 (petroleum ether/ethyl acetate 95/5); ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.10 (s, 9H), 1.85 (d, J = 12.2 Hz, 1H), 2.31−2.44 (m, 1H), 2.38 (dd, J = 1.3, 8.8 Hz, 1H), 3.01−3.13 (m, 1H), 3.36 (t, J = 7.3 Hz, 1H), 5.77−5.97 (m, 3H), 6.11−6.20 (m, 1H); ^{13}C {^{1}H} NMR (50 MHz, $CDCl_3$) δ −0.6 (s, CH_3), 30.5 (s, CH_2), 38.3 (s, CH), 51.5 (s, CH), 56.6 (s, CH), 125.2 (s, CH), 126.4 (s, CH), 129.8 (s, CH), 137.7 (s, CH), 214.5 (s, C═O); HRMS (ESI-MS) $[M + K]^+$ found 245.0761, calcd for $C_{12}H_{18}KOSi$ 245.0758.

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Supporting Information Available: ^{1}H and ^{13}C NMR spectra of all new compounds; NOESY spectra; crystallographic information files (CIF). This material is available free of charge via the Internet at http://pubs.acs.org. In addition, crystallographic data for the structure of **2** and **10** were deposited in the Cambridge Crystallographic Data Centre under the number CCDC 724330 and 724331, respectively. They are available free of charge at http://www.ccdc.cam.ac.uk.

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