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Intramolecular carbolithiation promoted by a DTBB-catalysed chlorine–lithium exchange

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Dedicated to Professor Reinhard W. Hoffmann on occasion of his 70th birthday

Abstract—The reaction of 6-chlorohex-1-ene **1** with lithium powder and a catalytic amount of 4,4′-di-*tert*-butylbiphenyl (DTBB, 5% molar) in THF at −78°C gives the corresponding organolithium intermediate **2**, which by reaction with different electrophiles affords, after hydrolysis with diluted hydrochloric acid, the expected products **3**. The same reaction performed at −30°C gives cyclopentyl derivatives **5**, probably by cyclisation of the open-chain intermediate **2** to give the cyclic organolithium compound **4**. When the double bond in the starting material contains an alkyl substituent, for instance compounds **6** and **9**, the corresponding cyclisation is inhibited, so the corresponding acyclic products **8** and **11** are respectively, obtained. However, when the substituent at the same positions is a phenyl group, like in starting materials **12** and **15**, the cyclised products **14** and **17** were respectively, isolated. In the case of the secondary starting chlorinated material **18**, the reaction can be directed to both, the acyclic products **20** or the cyclic ones **22**, working at −78 or −30°C, respectively, as it happens in the case of the unsubstituted chlorinated material **1**. For the tertiary chloro derivative **23**, only the cyclic compound **27** could be isolated at −30°C due to the great instability of the corresponding tertiary organolithium intermediate **24**, which undergoes a proton abstraction even at −78°C. From allyl 2-chlorophenyl ether **28** or *N*,*N*-diallyl-2-chloroaniline **32**, only the corresponding cyclic compounds **31** and **33**, respectively, are isolated either at −78 or at −30°C. In all cases a carbanionic cyclisation, better than a radical one, is postulated to occur as mechanistic pathway.

1. Introduction

Organolithium reagents usually react as nucleophiles towards polarised multiple bonds, the addition to carbonyl compounds being a classical example of this process.[1] As a consequence of that, the addition to a non-polarised carbon–carbon double bond, the so-called carbolithiation,[2] is not a simple reaction. However, from a synthetic point of view, the carbolithiation is an interesting process because a new organolithium reagent is formed, which can react with a typical electrophile to introduce an electrophilic fragment in the new backbone. It means that through the mentioned process it is possible to modify both the carbon chain and the functionality in only one methodological operation. In addition, two possibilities are opened concerning the inter- and intramolecular fashion of the carbolithiation reaction, in the second case allowing the generation of cyclic systems during the creation of the new carbon–carbon σ-bond, so making possible the preparation of functionalised carbocyclic compounds in a direct manner.[3] Among the different methodologies to generate unsaturated organolithiums, which are necessary starting materials for the intramolecular cyclisation, we can cite: (a) bromine- or iodine–lithium exchange using an alkyllithium reagent;[4] (b) sulphur–lithium exchange[5] starting from phenyl thioethers using a lithium–arene;[6] (c) tin–lithium transmetallation from tri-*n*-butylstannanes and *n*-butyllithium;[7] and (d) cyano-lithium exchange using a lithium–arene in especial cases.[8] However, to the best of our knowledge, the most general way (a) has never been applied to the most accessible and stable chlorinated unsaturated materials due to the difficulty of performing the corresponding lithiation (chlorine–lithium exchange) at low temperatures by using conventional methodologies. We found some years ago[9] that the use of an excess of lithium powder and a catalytic amount of an arene [naphthalene and 4,4′-di-*tert*-butylbiphenyl (DTBB) being the most commonly used[10]] is an adequate procedure to carry out chlorine–lithium exchange under very mild reaction conditions.[11–14] Thus, this methodology (arene-catalysed lithiation) has been intensively used for performing new reactions such as the generation of simple organolithium reagents from non-halogenated materials,[15] the preparation of very unstable functionalised organolithium intermediates[16] (by halogen–lithium exchange[17] or by reductive ring opening of different heterocycles[18]), the generation of dilithium synthons,[19] and the activation of

Keywords: chlorine–lithium exchange; intramolecular carbolithiation; DTBB-catalysed lithiation; cyclisation.

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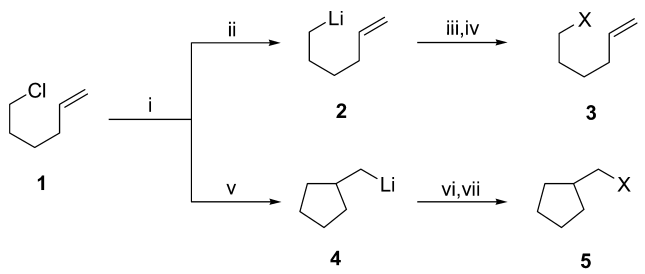
other metals,[20] especially nickel[21] and copper.[22] In this paper we describe the application of the mentioned arene-catalysed lithiation to the generation of unsaturated organolithium compounds by chlorine–lithium exchange in order to study their possible intramolecular carbolithiation reaction.[23]

2. Results and discussion

The reaction of commercially available 6-chlorohex-1-ene (**1**) with a slight excess of lithium powder (1:2.8 molar ratio; theoretical 1:2) and a catalytic amount of DTBB (5 mol%) in THF at −78°C led to a solution of the corresponding organolithium intermediate **2**, which by treatment with different electrophiles [E=Bu^{t}CHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe] and final hydrolysis with 2 M HCl, both at the same temperature, gave the expected products **3** (Scheme 1 and Table 1). Pentan-3-one was used as the standard electrophile in order to find the best reaction conditions (Table 1, entries 1–5). Thus, using 5 mol% of DTBB as the catalyst, we found that working at −78°C the best reaction time for the lithiation and the reaction with the electrophile were 45 and 15 min, respectively (Table 1, entry 1), these reaction conditions being applied to the other electrophilic reagents (Table 1, entries 6–9). On the other hand, the use of Barbier-type reaction conditions (lithiation in the presence of the electrophile)[24] did not improve the obtained results (Table 1, entry 2 and footnote c). In addition, when naphthalene was used as the electron carrier agent under catalytic[9,11–14] or stoichiometric[25] conditions (Table 1, entries 4 and 5, as well as footnotes d and e, respectively) the corresponding yields were not improved; however, in the catalytic version with naphthalene the results are comparable to those obtained with DTBB, so both electron-carrier agents can be used. A final remark has to do with the use of longer reaction times, either in the lithiation or in the S_E reaction steps, which did not improve the corresponding yields (Table 1, entries 1 and 3). On the other hand, concerning the use of the corresponding brominated starting material, we obtained comparable results (Table 1, entry 2 and footnote b), so we decided to continue in the rest of this study with the cheaper and more stable chlorinated materials (see below).



Scheme 1. *Reagents and conditions*: (i) Li powder, DTBB (5 mol%), THF; (ii) −78°C; (iii) E=Bu^{t}CHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, −78°C; (iv) 2 M HCl, −78°C to room temperature; (v) −30°C; (vi) E=Bu^{t}CHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, −30°C; (vii) 2 M HCl, −30°C to room temperature.

When the above mentioned reaction was carried out at −30°C, the cyclic intermediate **4** was the only one generated [probably through intermediate **2** initially formed via an intramolecular carbolithiation process (see below)], which by reaction with the same electrophiles as for compound **2** [E=Bu^{t}CHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe] gave compounds **5**, after hydrolysis with 2 M HCl, both steps being performed at the same temperature (Scheme 1 and Table 2). The following remarks are pertinent: (a) although the reaction can be performed at temperatures ranging between −78 and 0°C (Table 2, entry 3 and footnote d), the best results were obtained at −30°C, so this temperature was chosen as the standard one for all electrophiles (Table 2, entries 1, 2 and 4–10); (b) the amount of the catalyst (DTBB) can be decreased until about 1% (Table 2, entries 5 and 6, and footnotes f and g), working in any case nicely. Even in absence of the catalyst the reaction worked well (Table 2, entry 2 and footnote c), this behaviour being observed in other cases at −30°C;[9] however, in this case the reaction time is longer and the process is not so clean, a careful purification being necessary; (c) when 6-bromohex-1-ene was used as starting material under the same reaction conditions a lower yield was obtained (Table 2, entry 1 and footnote b).

We then studied the influence of the substitution on the double bond in the cyclisation process shown in Scheme 1. Thus, 6-chloro-2-propylhex-1-ene (**6**) was submitted to the DTBB-catalysed lithiation at temperatures ranging between

Table 1. Preparation of compounds **3**

Entry	Reaction time (min)		Electrophile	Product		
	Lithiation	S_E reaction	E	No	X	Yield (%)[a]
1	45	15	Et_2CO	**3a**	Et_2COH	95
2	75[b]		Et_2CO	**3a**	Et_2COH	90[b] (85)[c]
3	70	30	Et_2CO	**3a**	Et_2COH	64
4	30	15	Et_2CO	**3a**	Et_2COH	89[d]
5	60	30	Et_2CO	**3a**	Et_2COH	33[e]
6	45	15	Bu^{t}CHO	**3b**	Bu^{t}CHOH	91
7	45	15	PhCHO	**3c**	PhCHOH	97
8	45	15	$(CH_2)_5CO$	**3d**	$(CH_2)_5COH$	90
9	45	15	PhCOMe	**3e**	PhC(OH)Me	77

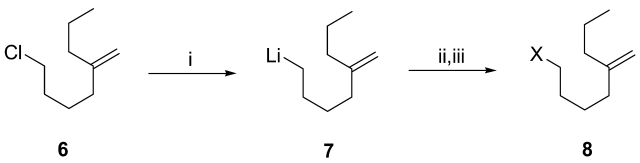
[a] Isolated yield of ≥95% pure (300 MHz ^{1}H NMR and/or GLC) compounds **3** after column chromatography (silica gel, hexane/ethyl acetate) based on the starting material **1**.
[b] Yield corresponding to the reaction starting from 6-bromohex-1-ene instead of compound **1** under the same reaction conditions.
[c] The lithiation reaction was performed in the presence of the electrophile (Barbier-type conditions).
[d] Naphthalene (5 mol%) was used as the electron-carrier catalyst.
[e] Lithium naphthalenide was used as the lithiating agent (stoichiometric version).

Table 2. Preparation of compounds **5**

Entry	Reaction time (min)		Electrophile		Product	
	Lithiation	S_E reaction	E	No	X	Yield (%)[a]
1	45	15	Et_2CO	**5a**	Et_2COH	95 (74)[b]
2	50	30	Et_2CO	**5a**	Et_2COH	83[c]
3	90	15	Et_2CO	**5a**	Et_2COH	53[d]
4	60	30	Et_2CO	**5a**	Et_2COH	80[e]
5	45	15	Et_2CO	**5a**	Et_2COH	83[f]
6	45	15	Et_2CO	**5a**	Et_2COH	93[g]
7	45	15	Bu^tCHO	**5b**	Bu^tCHOH	75
8	45	15	PhCHO	**5c**	PhCHOH	87
9	45	15	$(CH_2)_5CO$	**5d**	$(CH_2)_5COH$	95
10	45	15	PhCOMe	**5e**	PhC(OH)Me	81

[a] Isolated yield of ≥95% pure (300 MHz ^1H NMR and/or GLC) compounds **5** after column chromatography (silica gel, hexane/ethyl acetate) based on the starting material **1**.
[b] Yield corresponding to the reaction starting from 6-bromohex-1-ene instead of compound **1**.
[c] The lithiation reaction was performed in the absence of the electron-carrier arene.
[d] The lithiation was carried out at −78°C allowing the temperature to rise to 0°C before S_E reaction and the corresponding hydrolysis with 2 M HCl.
[e] The whole process was performed at 0°C.
[f] 2.5 mol% of DTBB was used as the catalyst.
[g] 1 mol% of DTBB was used as the catalyst.

−78°C and room temperature, giving in all cases the corresponding 'open' intermediate **7** and the final products **8**, after successive reaction with different electrophiles [E=Bu^tCHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, Me_3SiCl] and final hydrolysis with 2 M HCl (Scheme 2 and Table 3). Even using mixtures of other solvents (pentane, ether) with THF or some additives (TMEDA or PMDTA)[26] we never got the corresponding cyclised intermediates and products. Anyhow, the process at −78°C resulted very clean, so we decided to prepare compounds **8** at this temperature and using the catalyst in 5 mol% amount. In addition, when the reaction was carried out with pentan-3-one as electrophile and under Barbier-type reaction conditions the yield was lower (Table 3, entry 2 and footnote b), so we worked in all cases in a two-step reaction manner (Grignard-type conditions).



Scheme 2. *Reagents and conditions*: (i) Li powder, DTBB (5 mol%), THF, −78°C; (ii) E=Bu^tCHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, Me_3SiCl, −78°C; (iii) 2 M HCl, −78°C to room temperature.

Table 3. Preparation of compounds **8**

Entry	Reaction time (min)		Electrophile		Product	
	Lithiation	S_E reaction	E	No	X	Yield (%)[a]
1	40	30	Et_2CO	**8a**	Et_2COH	63
2	60[b]		Et_2CO	**8a**	Et_2COH	43[b]
3	40	30	Bu^tCHO	**8b**	Bu^tCHOH	74
4	40	30	PhCHO	**8c**	PhCHOH	62
5	40	30	$(CH_2)_5CO$	**8d**	$(CH_2)_5COH$	76
6	40	30	PhCOMe	**8e**	PhC(OH)Me	60
7	40	30	Me_3SiCl	**8f**	Me_3Si	63

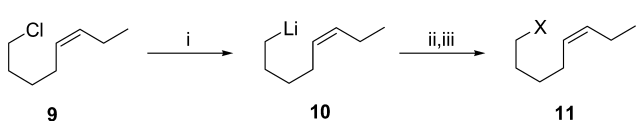
[a] Isolated yield of ≥95% pure (300 MHz ^1H NMR and/or GLC) compounds **8** after column chromatography (silica gel, hexane/ethyl acetate) based on the starting material **6**.
[b] The lithiation reaction was performed in the presence of the electrophile (Barbier-type conditions).

The starting material **6**[27] was prepared by Wittig methylenation of 8-chlorooctan-4-one,[28] which was obtained from commercially available 5-chlorovaleronitrile by addition of *n*-propylmagnesium chloride and further hydrolysis, following literature procedures.

When the substitution in the unsaturated chlorinated material was at the first carbon atom we obtained the same results as indicated in Scheme 2. Thus, (*Z*)-8-chlorooct-3-ene (**9**) was submitted to the same protocol as it was described in Scheme 2 (−78°C, DTBB 5 mol%) giving products **11**, after reaction of intermediate **10** with different electrophiles [E=Bu^tCHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, Me_3SiCl] and final hydrolysis with diluted 2 M HCl (Scheme 3 and Table 4). As it happened for the starting material **6**, different changes in temperature, co-solvents and additives (see above) did not produce the possible cyclisation to give the corresponding cyclic organolithium intermediates and products. Also here, the lithiation in the presence of the electrophile (Barbier-type reaction conditions) did not improve the results obtained in the two-step process (Table 4, entry 2 and footnote b).

The starting material **9** was prepared by reaction of commercially available (*Z*)-5-octen-1-ol with triphenylphosphane in carbon tetrachloride.[29]

A very different behaviour was observed when the substitutent at the double bond was a phenyl group. For

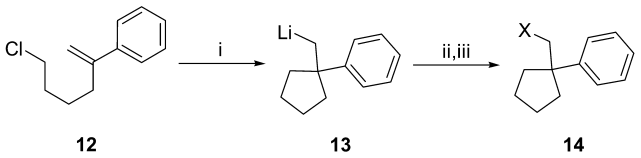


Scheme 3. *Reagents and conditions*: (i) Li powder, DTBB (5 mol%), THF, −78°C; (ii) E=Bu^tCHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, Me_3SiCl, −78°C; (iii) 2 M HCl, −78°C to room temperature.

Table 4. Preparation of compounds **11**

Entry	Reaction time (min)		Electrophile		Product	
	Lithiation	S_E reaction	E	No	X	Yield (%)[a]
1	30	20	Et_2CO	**11a**	Et_2COH	77
2	90[b]		Et_2CO	**11a**	Et_2COH	48[b]
3	30	20	Bu^tCHO	**11b**	Bu^tCHOH	67
4	30	20	PhCHO	**11c**	PhCHOH	76
5	30	20	$(CH_2)_5CO$	**11d**	$(CH_2)_5COH$	77
6	30	20	PhCOMe	**11e**	PhC(OH)Me	72
7	30	20	Me_3SiCl	**11f**	Me_3Si	72

[a] Isolated yield of ≥95% pure (300 MHz ^1H NMR and/or GLC) compounds **11** after column chromatography (silica gel, hexane/ethyl acetate) based on the starting material **9**.
[b] The lithiation reaction was performed in the presence of the electrophile (Barbier-type conditions).



Scheme 4. *Reagents and conditions*: (i) Li powder, DTBB (5 mol%), THF, −78°C; (ii) E=Bu^{t}CHO, PhCHO, Et_2CO, −78°C; (iii) 2 M HCl, −78°C to room temperature.

Table 5. Preparation of compounds **14**

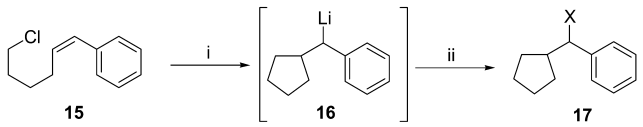
Entry	Reaction time (min)		Electrophile	Product		
	Lithiation	S_E reaction	E	No	X	Yield (%)[a]
1	60	15	Et_2CO	**14a**	Et_2COH	38
2	90		Et_2CO	**14a**	Et_2COH	35[b]
3	60	15	Et_2CO	**14a**	Et_2COH	35[c]
4	60	15	Et_2CO	**14a**	Et_2COH	20[d]
5	60	15	Bu^{t}CHO	**14b**	Bu^{t}CHOH	25
6	60	15	PhCHO	**14c**	PhCHOH	25

[a] Isolated yield of ≥95% pure (300 MHz ^{1}H NMR and/or GLC) compounds **14** after column chromatography (silica gel, hexane/ethyl acetate) based on the starting material **12**.
[b] The lithiation reaction was performed under Barbier-type conditions.
[c] The reaction was performed at −30°C.
[d] The lithiation reaction was performed at −30°C and under Barbier-type conditions.

6-chloro-2-phenylhex-1-ene (**12**) the DTBB-catalysed lithiation even at −78°C gave already the cyclic intermediate **13** (probably formed by an intramolecular carbolithiation), which by reaction with some electrophiles (E=Bu^{t}CHO, PhCHO, Et_2CO) afforded, after hydrolysis with 2 M HCl, the corresponding products **14** (Scheme 4 and Table 5). The conversion is total after about 1 h (the starting material disappeared), so the rest of the starting material was transformed into a mixture of compounds, among them the 'reduced' product (**14** with X=H) resulting from a lithium–hydrogen exchange by intermediate **13**. This hydrogen abstraction from the reaction medium, probably from THF at the α-position, has already been observed in other cases for very reactive organolithium intermediates.[30] Anyhow, we never detected (GLC-MS) in the reaction mixture the product resulting from the reaction of the 'open' intermediate with the electrophile. As Table 5 shows, the use of Barbier-type reaction conditions did not improve the obtained results (Table 5, entries 2 and 4).

The starting material **12** was prepared by lithiation of α-bromostyrene with *n*-butyllithium at −78°C followed by reaction with 1-chloro-4-iodobutane.[31]

When (*Z*)-6-chloro-1-phenylhex-1-ene (**15**) was lithiated under DTBB-catalysis, we always obtained the cyclised products **17** either at −78 or at −30°C, so after the first chlorine–lithium exchange a carbolithiation took place to yield the intermediate **16**, which by reaction with some electrophiles (E=PhCHO, Et_2CO, Me_3SiCl) and final hydrolysis gave the mentioned products **17** (Scheme 5 and Table 6). At −78°C the reaction under Barbier-type conditions did not work (Table 6, entry 2). On the contrary, at −30°C it was necessary to work under Barbier-type conditions in order to achieve the expected products



Scheme 5. *Reagents and conditions*: (i) Li powder, DTBB (5 mol%), E=PhCHO, Et_2CO, Me_3SiCl, THF, −30°C; (ii) 2 M HCl, −30°C to room temperature.

Table 6. Preparation of compounds **17**

Entry	Reaction time (min)		Electrophile	Product		
	Lithiation	S_E reaction	E	No	X	Yield (%)[a]
1	45	15	Et_2CO	**17a**	Et_2COH	38[b]
2	45[c]		Et_2CO	**17a**	Et_2COH	–[c,d]
3	30	15	Et_2CO	**17a**	Et_2COH	–[d]
4	30[c]		Et_2CO	**17a**	Et_2COH	63
5	30[c]		PhCHO	**17c**	PhCHOH	70
6	30[c]		Me_3SiCl	**17f**	Me_3Si	80

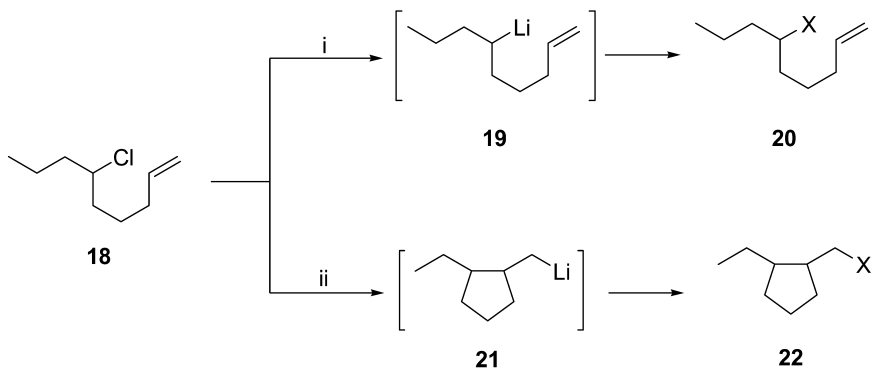
[a] Isolated yield of ≥95% pure (300 MHz ^{1}H NMR and/or GLC) compounds **17** after column chromatography (silica gel, hexane/ethyl acetate) based on the starting material **15**.
[b] The reaction was performed at −78°C.
[c] The lithiation reaction was performed under Barbier-type conditions at −78°C.
[d] No reaction product was detected (GLC-MS).

(Table 6, entries 4–6). Also in this case, the corresponding 'reduced' product (**17** with X=H) was the main by-product detected (GLC-MS).

The starting material **15** was prepared in a two-step process: (a) preparation of 6-chloro-1-phenylhex-1-yne by palladium and copper catalysed coupling of iodobenzene with 6-chloro-hex-1-yne[32] and (b) Lindlar hydrogenation of the triple bond to yield the *cis* chlorinated olefin.[33]

The next study on intramolecular carbolithiation of substituted chlorohexenes involved the starting material **18**. Its DTBB-catalysed lithiation at −78°C under Barbier conditions led to the formation of the intermediate **19**, which reacting with the electrophile [E=Bu^{t}CHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe] present in the reaction medium gave, after hydrolysis with 2 M HCl the expected compounds **20** (Scheme 6 and Table 7). When the same process was carried out in the absence of the electrophile (two-step reaction) the corresponding cyclised product of type **22** was exclusively obtained (see below). On the other hand when the reaction was carried out under Barbier conditions but at −30°C a mixture of both products **20** and **22**, was obtained (Table 7, entry 2). In addition, and working at −78°C under Barbier-type conditions, in some cases yields are low due to decomposition of the intermediate and the electrophile under the conditions assayed, none of the products being the corresponding cyclic products **22** (Table 7, entries 3, 4 and 6). Concerning stereochemical aspects, compounds **20** derived from prostereogenic carbonyl compounds gave a ca. 1:1 mixture of diastereomers (300 MHz ^{1}H NMR), which could not be separated by column chromatography (Table 7, entries 3, 4 and 6, and footnote d).

On the other hand, when the DTBB-catalysed lithiation of



Scheme 6. *Reagents and conditions*: (i) Li powder, DTBB (5 mol%), E=Bu^{t}CHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, THF, −78°C, then 2 M HCl; (ii) Li powder, DTBB (5 mol%), E=Bu^{t}CHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, Me_2CO, THF, −30°C, then 2 M HCl.

Table 7. Preparation of compounds **20**

Entry	Reaction time (min)		Electrophile		Product	
	Lithiation	S_E reaction	E	No	X	Yield (%)[a]
1	70		Et_2CO	**20a**	Et_2COH	60
2	30[b]		Et_2CO	**20a**	Et_2COH	73[b,c]
3	70		Bu^{t}CHO	**20b**	Bu^{t}CHOH	17[d]
4	70		PhCHO	**20c**	PhCHOH	28[d]
5	70		$(CH_2)_5CO$	**20d**	$(CH_2)_5COH$	40
6	70		PhCOMe	**20e**	PhC(OH)Me	20[d]

[a] Isolated yield of ≥95% pure (300 MHz ^{1}H NMR and/or GLC) compound **20** after column chromatography (silica gel, hexane/ethyl acetate) based on the starting material **18**.
[b] The lithiation reaction was performed in at −30°C.
[c] A 1:1.7 mixture of compounds **20/22** was obtained (GLC).
[d] A ca. 1:1 mixture of diastereomers was isolated (300 MHz ^{1}H NMR).

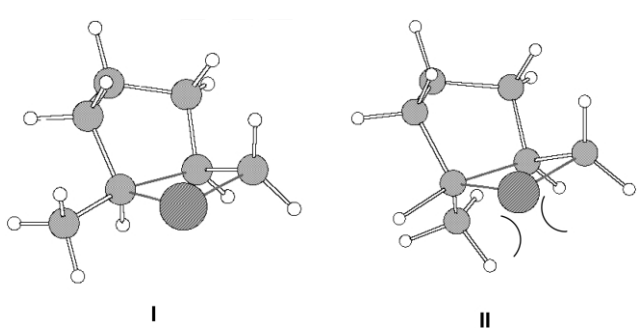
compound **18** above mentioned (Scheme 6) was carried out also in the presence of the electrophile for 90 min but at −30°C the intermediate formed was the corresponding cyclic one **21**, so its reaction with electrophiles [E= Bu^{t}CHO, PhCHO, Et_2CO, $(CH_2)_5CO$, PhCOMe, Me_2CO] followed by hydrolysis with 2 M HCl gave the corresponding products **22** (Scheme 6 and Table 8). For shorter addition times a mixture of both products **20** and **22** was isolated (Table 8, entry 2). The corresponding two-step process, either at −30°C (Table 8, entry 3), 0°C (Table 8, entry 4) or −78°C (Table 8, entry 5) gave any improvement in the yields. An additional comment has to do with reaction times under the same reaction conditions: we observed that in some cases the lithiation step worked differently depending on the carbonyl compound used as electrophile (see, for instance, Table 8, entries 8 and 10) under Barbier conditions. This fact has been already observed in our group (for instance benzaldehyde usually works better as cyclohexanone in lithiations under Barbier conditions[34]) and would suggest some participation of the carbonyl group in the electron-carrying process. Finally, also in the case of compounds **22**, the use of prostereogenic carbonyl compounds provokes the appearance of diastereomers as a ca. 1:1 diastereomers mixture (300 MHz ^{1}H NMR and/or GLC; Table 8, entries 6, 7 and 9, and footnote e), which in the case of the benzaldehyde derivatives could be separated chromatographically (silica gel, hexane/ethyl acetate).

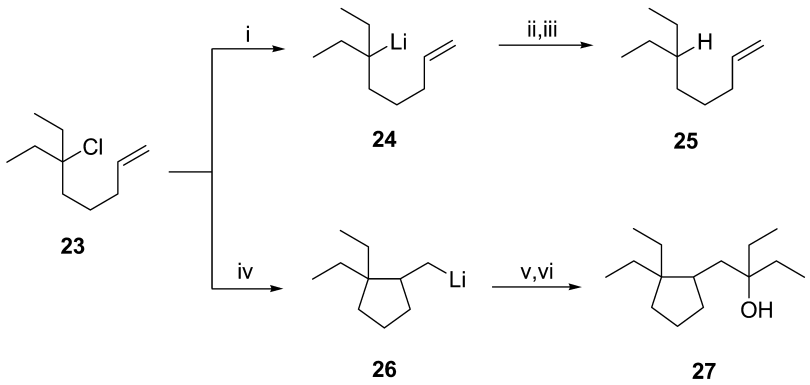
Table 8. Preparation of compounds **22**

Entry	Reaction time (min)		Electrophile		Product	
	Lithiation	S_E reaction	E	No	X	Yield (%)[a]
1	90		Et_2CO	**22a**	Et_2COH	68
2	30		Et_2CO	**22a**	Et_2COH	73[b]
3	20	10	Et_2CO	**22a**	Et_2COH	62
4	10[c]	10[c]	Et_2CO	**22a**	Et_2COH	45[c]
5	80[d]	45[d]	Et_2CO	**22a**	Et_2COH	51[d]
6	90		Bu^{t}CHO	**22b**	Bu^{t}CHOH	46[e]
7	90		PhCHO	**22c**	PhCHOH	63[e]
8	120		$(CH_2)_5CO$	**22d**	$(CH_2)_5COH$	49
9	90		PhCOMe	**22e**	PhC(OH)Me	44[e]
10	120		Me_2CO	**22 g**	Me_2COH	43

[a] Isolated yield of ≥95% pure (300 MHz ^{1}H NMR and/or GLC) compounds **20** after column chromatography (silica gel, hexane/ethyl acetate) based on the starting material **18**.
[b] A 1:1.7 mixture of compounds **20/22** was obtained (GLC).
[c] The lithiation reaction was performed at 0°C.
[d] The lithiation reaction was performed at −78°C.
[e] A ca. 1:1 diastereomers mixture (at the carbon-hydroxy sterocenter) was obtained (300 MHz ^{1}H NMR and/or GLC).

In the case of compounds **22** we obtained only one diastereomer concerning the two substituents at the five-membered ring. In the literature, different stereochemical results have been obtained depending on the reaction conditions. For instance, starting from 6-iodohept-1-ene, the lithiation with lithium at 0°C gave mainly intermediate *cis*-**21** (*cis*/*trans*: 5/1 after protonation).[35a] The same results were obtained when the same process was initiated by phenyllithium as a catalyst at different temperatures (−20 to 60°C; *cis*/*trans*: 2.9–4.7/1), supporting in this case a radical mechanism for the cyclisation.[4a] In addition, using *tert*-butyllithium as the lithiating agent and starting from the same material, the *cis*/*trans* ratio strongly depends from





Scheme 7. *Reagents and conditions*: (i) Li powder, DTBB (5 mol%), THF, −78°C; (ii) Et_2CO, −78°C; (iii) 2 M HCl, −78°C to room temperature; (iv) Li powder, DTBB (5 mol%), THF, −30°C; (v) Et_2CO, −30°C; (vi) 2 M HCl, −30°C to room temperature.

the reaction conditions (*cis*/*trans*: 1.5/1 or <1/44).[35b] Finally, a graphical simulation of the two possible topicities shows that the *trans* representation (**II**) is more hindered than the corresponding *cis* one (**I**).[36] In our case, we probably obtained the intermediate *cis*-**21** and the corresponding products *cis*-**22**, but at this moment the alternative *trans*-structures can not be ruled out.[37]

The starting material **18** was prepared by addition of 4-pentenylmagnesium bromide to butanal, following by hydroxy/chlorine exchange with triphenylphosphane and carbon tetrachloride.[29]

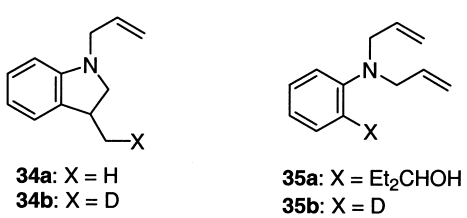
When the carbolithiation reaction was applied to the tertiary derivative **23** we found that at −78°C the corresponding intermediate **24** initially formed was very unstable and abstracts a proton from the reaction medium (probably from THF),[30] so after adding pentan-3-one as electrophile the only reaction product detected (GLC-MS) was the 'reduced' compound **25**, resulting from a lithium–hydrogen exchange [two-step reaction/−78°C: 61% (GLC); Barbier conditions/−78°C: 60% (GLC)]. It is worthy to note that even working under Barbier conditions, only compound **25** was obtained at −30°C [53% (GLC)]. However, at 0°C under Barbier conditions (76%) or at −30°C in a two-step process (75%), the expected cyclic product **27** was the only one isolated after reaction with pentan-3-one and final hydrolysis with 2 M HCl at the same temperature, intermediate **26** being probably involved in the lithiation step (Scheme 7).

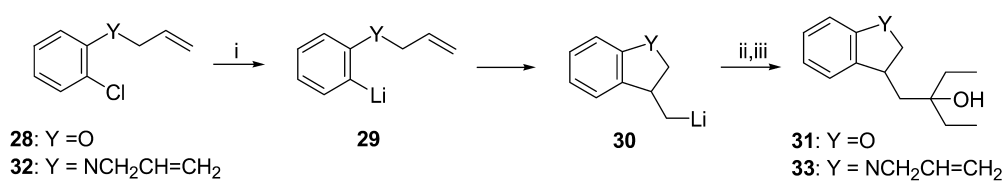
The starting material **23** was prepared from the corresponding tertiary alcohol (obtained by lithiation of commercially available 5-bromopent-1-ene followed by reaction with pentan-3-one) by reaction with concentrated hydrochloric acid.[38]

Finally, we studied the DTBB-catalysed lithiation of compound **28** finding that either at −78°C (ca. 45%) or at −30°C (56%) the only compound isolated, after reaction with pentan-3-one and final hydrolysis, was the alcohol **31**, intermediates **29** (Y=O) and **30** (Y=O) being probably involved in the process (Scheme 8). In this case, no compound resulting from the reaction of intermediate **29** (Y=O) with the electrophile was obtained. The moderate yield obtained is probably due to by-reactions such as partial deallylation[39] or intramolecular deprotonation at the allylic position[40] followed by a Wittig rearrangement.[41]

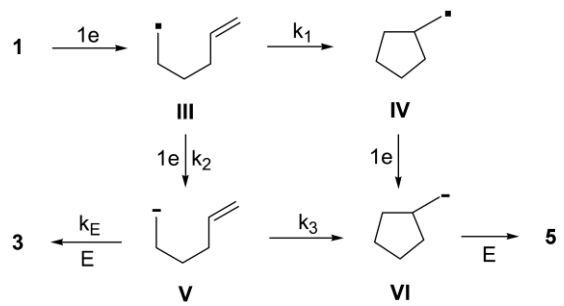
The starting ether **28**[42] was prepared by allylation of commercially available 2-chlorophenol with allyl bromide in the presence of sodium hydride.

When the starting material was the diallylamine **32**, the lithiation at −78°C under the reaction conditions described above gave, after reaction with deuterium oxide, a mixture of the cyclic product **34b** and the acyclic one **35b** in a 1.3:1 molar ratio. This behaviour is independent on the electrophile because using pentan-3-one under the same reaction conditions we obtained the same ratio of compounds **33** and **35a**, respectively (70–80% yield in both cases). However, working at −30°C only the cyclic intermediate **30** (Y=$NCH_2CH{=}CH_2$) was generated giving, after reaction with pentan-3-one and final hydrolysis with 2 M HCl, the expected product **33** in 41% isolated yield, together with the 'reduced' product **34a**, resulting from a lithium–hydrogen exchange from intermediate **30** (Y=$NCH_2CH{=}CH_2$), either from tetrahydrofuran (see above) or from the ketone at the α-position. The second possibility is the most





Scheme 8. *Reagents and conditions*: (i) Li powder, DTBB (5 % molar), THF, −78 or −30°C; (ii) Et_2CO, same temperature as step i; (iii) 2 M HCl, −78 or −30°C to room temperature.



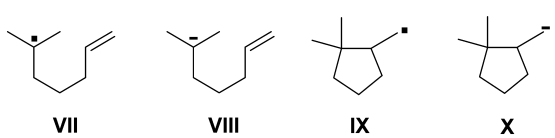
Scheme 9.

probable, because when the same reaction was performed using water or deuterium oxide as electrophiles, the expected products **34a** and **34b** were isolated in 81 and 85% (95% deuterium incorporation), respectively.

The diallylamine **32** was prepared by successive reaction of commercially available 2-chloroaniline with *n*-butyllithium and allyl bromide, this process being repeated twice.

Concerning the possible mechanism of the reaction, which is illustrated in Scheme 9 for the simplest non-substituted system derived from the starting material **1**, we think that radical of type **III** is initially formed, which could either cyclise to the new radical **IV** or take a second electron giving the carbanion **V**. Since the cyclisation of the radical is much more rapid than that of the carbanion,[43] we think that once the radical **III** is formed at −78°C it is converted rapidly to the anion **V** ($k_2 \gg k_1$) whereas, at −30°C cyclisation of intermediate **V** to the cyclic carbanion **VI** probably occurs. Actually, the other possible pathway at −30°C, through intermediate **VI** can not be completely ruled out. However, we observed that performing the reaction in the presence of cumene as effective radical scavenger,[4a] the obtained results were not altered significantly, so we deduce that the half-live of radicals **III** and **IV** should be very short. On the other hand, since the reaction under Barbier-type conditions gives similar results as in the two-step process, we conclude that the cyclisation **V→VI** is faster than the S_E reaction of carbanion **V** ($k_3 \gg k_E$) (Scheme 9).

For systems substituted at the double bond, we observed that the cyclisation step of type **III→IV** (or **V→VI**) is highly affected by stereoelectronic effects, so it did not take place when the substituents at the double bond are alkyl groups (see Schemes 2 and 3), thus supporting an anionic cyclisation. However the cyclisation is the exclusive process for the corresponding phenyl substituted systems, which give either a primary (see intermediate **13**) or a more stable benzylic intermediate (see **16**). For secondary intermediates (see **19**) the reaction can be directed to both acyclic and cyclic products, involving intermediates of type **V** and **VI**, respectively. Finally, in the case of the tertiary derivative **24**, the radical **VII** evolves rapidly at −78°C to the carbanion **VIII**, which is very unstable and takes a proton from the reaction medium. At −30°C intermediate **VIII** probably gives the most stable primary cyclic carbanion **X**. As it was above commented, radical **IX**, resulting from the radical **VII** by cyclisation, probably does not take part in the reaction.



Finally, for aromatic chlorides, intermediates **29** suffer rapid cyclisation to the corresponding primary organolithium compounds of type **30**, indicating again that the transformation **V→VI** (or **III→IV**, for the radical mechanism) is a very favourable process.

3. Conclusion

In conclusion, we report in this paper the DTBB-catalysed lithiation of 6-chlorohex-1-ene and related systems, which can be in general controlled giving the corresponding open-chain compounds or the cyclic derivatives, depending on the substituents and the reaction conditions. We believe that in the case of cyclisation processes an intramolecular carbolithiation takes place transforming the initially formed organolithium intermediate into the corresponding cyclic one. Anyhow, the reported methodology can be useful from a synthetic point of view, especially when functionalised carbocycles are produced.

4. Experimental

4.1. General

All lithiation reactions were carried out under argon atmosphere in oven-dried glassware. All commercially available reagents (Acros, Aldrich, Fluka) were used without further purification, except in the case of electrophiles, which were used freshly distilled. Commercially available anhydrous THF (99.9%, water content ≤0.006%, Acros) was used as solvent in all the lithiation reactions. IR spectra were measured (film) with a Nicolet Impact 400 D-FT Spectrometer. NMR spectra were recorded with a Bruker AC-300 using $CDCl_3$ as solvent and TMS as internal standard; chemical shifts are given in ppm and coupling constants (*J*) are given in Hz. ^{13}C NMR assignments were made on the basis of DEPT experiments. LRMS were measured with Shimadzu GC/HS QP-5000 and Hewlett–Packard EM/CG-5973A spectrometers, and HRMS were measured with Finingan MAT95 S spectrometer, fragment ions in *m*/*z* with relative intensities (%) in parentheses. The purity of volatile products and the chromatographic analyses (GLC) were determined with a Hewlett–Packard HP-4890 instrument equipped with a flame ionisation detector and a 30 m capillary column (0.32 mm diam., 0.25 μm film thickness), using nitrogen (2 mL/min) as carrier gas, $T_{injector}$=275°C, $T_{detector}$=300°C, T_{column}=60°C (3 min) and 60–270°C (15°C/min), *P*=40 KPa. Thin layer chromatography (TLC) was carried out on Merck plastic sheets coated with silica gel 60 F_{254}. Lithium powder was prepared from commercially available lithium granules (99%, high sodium content, Aldrich) as it was already reported by us.[44]

4.2. DTBB-catalysed lithiation of 6-chlorohex-1-ene (1)

4.2.1. Preparation of compounds 3. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (26.6 mg, 0.1 mmol) in THF (4 mL) at −78°C was added 6-chlorohex-1-ene (**1**; 0.138 mL, 1.0 mmol) under an argon atmosphere. The colour disappeared after the substrate addition, the reaction mixture was stirred until the green colour was recovered (45 min) and the corresponding electrophile (1.1 mmol) was then added. The resulting mixture was stirred for 15 min at the same temperature (−78°C), then it was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature for 10 min. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and was concentrated under vacuum (15 Torr). Compounds **3** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in Table 1; physical and spectroscopic data, as well as references for known compounds, follows.

Barbier type reaction. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (26.6 mg, 0.1 mmol) in THF (4 mL) at −78°C was added a solution of 6-chlorohex-1-ene (**1**; 0.138 mL, 1.0 mmol) and pentan-3-one in THF (1.5 mL) over a 30 min period, the reaction was stirred for 15 additional minutes at the same temperature and then quenched and worked-up as above.

4.2.1.1. 3-Ethylnon-8-en-3-ol (3a).[45] R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3416 (OH), 3077, 1641 cm^{-1} (C=C); δ_H 0.78 (t, J=7.3 Hz, 6H, 2×CH_3), 1.31 (m, 11H, 5×CH_2 and OH), 2.00 (m, 2H, CH_2=CHCH_2), 4.87 (d, J=10.4 Hz, 1H, CHH=), 4.93 (d, J=17.4 Hz, 1H, CHH=), 5.74 (m, 1H, =CH); δ_C 7.7 (2×CH_3), 22.8, 29.5, 31.0, 31.3, 33.7, 38.0 (6×CH_2), 74.6 (COH), 114.3 (CH_2=), 138.9 (=CH); m/z 152 (M^+−18, 0.3%), 141 (15), 123 (15), 87 (91), 81 (18), 69 (31), 67 (14), 57 (100), 55 (40), 53 (10), 45 (67), 43 (42), 41 (74).

4.2.1.2. 2,2-Dimethylnon-8-en-3-ol (3b).[46] R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3394 (OH), 3077, 1641 cm^{-1} (C=C); δ_H 0.89 (s, 9H, 3×CH_3), 1.41 (m, 7H, 3×CH_2 and OH), 2.06 (m, 2H, CH_2=CHCH_2), 3.19 (m, 1H, CHOH), 4.94 (d, J=11.0 Hz, 1H, CHH=), 5.00 (d, J=17.1 Hz, 1H, CHH=), 5.82 (m, 1H, =CH); δ_C 25.6 (3×CH_3), 26.6, 28.9, 31.3, 33.8 (4×CH_2), 34.9 [$C(CH_3)_3$], 79.9 (CHOH), 114.3 (CH_2=), 139.0 (=CH); m/z 152 (M^+−18, 0.2%), 113 (11), 95 (95), 87 (21), 71 (17), 70 (13), 69 (48), 68 (18), 67 (28), 57 (73), 56 (19), 55 (33), 45 (37), 44 (12), 43 (76), 42 (11), 41 (100).

4.2.1.3. 1-Phenylhept-6-en-1-ol (3c).[47] R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3353 (OH), 3028, 3063, 3074, 1640 cm^{-1} (C=C); δ_H 1.43 (m, 4H, 2×CH_2), 1.74 (m, 4H, 2×CH_2), 4.63 (t, J=6.7 Hz, 1H, CHOH), 4.92 (d, J=10.4 Hz, 1H, CHH=), 4.97 (d, J=17.4 Hz, 1H, CHH=), 5.78 (m, 1H, CH_2=CH), 7.30 (m, 5H, ArH); δ_C 25.3, 28.7, 33.6, 38.9 (4×CH_2), 74.5 (CHOH), 114.3 (CH_2=), 125.8, 127.4, 128.4, 144.8 (6C, ArC), 138.8 (=CH); m/z 191 (M^++1, 0.4%), 190 (M^+, 3%), 133 (15), 120 (19), 107 (100), 105 (11), 91 (11), 79 (69), 77 (39), 51 (14), 41 (24).

4.2.1.4. 1-(Hex-5-enyl)cyclohexanol (3d).[48] R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3394 (OH), 3076, 1641 cm^{-1} (C=C); δ_H 1.23 (m, 3H, CH_2 and OH), 1.44 (m, 14H, 7×CH_2), 2.07 (m, 2H, CH_2=CHCH_2), 4.94 (d, J=11.6 Hz, 1H, CHH=), 5.00 (d, J=17.7 Hz, 1H, CHH=), 5.81 (m, 1H, =CH); δ_C 22.2, 22.3, 25.8, 29.5, 33.7, 37.4, 42.2 (9C, 9×CH_2), 71.4 (COH), 114.3 (CH_2=), 138.9 (=CH); m/z 164 (M^+−18, 1%), 99 (100), 98 (30), 83 (25), 82 (11), 81 (69), 79 (14), 71 (13), 69 (17), 68 (15), 67 (21), 58 (18), 57 (17), 55 (79), 53 (13), 43 (44), 42 (14), 41 (71).

4.2.1.5. 2-Phenyloct-7-en-2-ol (3e).[49] R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3438 (OH), 3074, 3026, 1640, 1601, 1494 cm^{-1} (C=C); δ_H 1.24 (m, 4H, 2×CH_2), 1.54 (s, 3H, CH_3), 1.79 (m, 2H, CH_2COH), 1.86 (s, 1H, OH), 1.97 (m, 2H, CH_2=CHCH_2), 4.89 (d, J=10.4 Hz, 1H, CHH=), 4.94 (d, J=17.1 Hz, 1H, CHH=), 5.74 (m, 1H, =CH), 7.31 (3m, 5H, ArH); δ_C 23.4, 29.1 (2×CH_2), 30.0 (CH_3), 33.6, 44.0 (2×CH_2), 74.6 (COH), 114.3 (CH_2=), 138.8 (=CH), 124.7, 126.4, 128.0, 148.0 (6C, ArC); m/z 204 (M^+, 0.2%), 122 (119), 121 (100), 118 (12), 105 (15), 91 (12), 77 (13), 43 (96), 41 (22).

4.2.2. Preparation of compounds 5. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (26.6 mg, 0.1 mmol) in THF (4 mL) at −30°C was added 6-chlorohex-1-ene (**1**; 0.138 mL, 1.0 mmol) under argon atmosphere. The colour disappeared after the substrate addition, the reaction mixture was stirred until the green colour was recovered (45 min) and the corresponding electrophile (1.1 mmol) was then added. The resulting mixture was stirred for 15 min at the same temperature (−30°C), then was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature for 10 min. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and was concentrated under vacuum (15 Torr). The compounds **5** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in Table 2; physical, spectroscopic and analytical data, as well as references for known compounds, follows.

4.2.2.1. 1-Cyclopentyl-2-ethylbutan-2-ol (5a).[45a] R_f 0.4 (hexane/ethyl acetate: 8/2); ν (film) 3415 cm^{-1} (OH); δ_H 0.79 (t, J=7.6 Hz, 6H, 2×CH_3), 1.18 (m, 4H, 2×CH_2), 1.49 (m, 8H, 4×CH_2), 1.76 (m, 3H, CH and CH_2); δ_C 7.9 (2×CH_3), 24.9 (2×CH_2), 31.3 (2×CH_2), 34.5 (2×CH_2), 35.7 (CH), 44.3 (CH_2), 75.1 (COH); m/z 152 (M^+−18, 1.9%), 141 (44), 123 (16), 87 (100), 83 (24), 81 (34), 73 (28), 69 (38), 67 (23), 59 (14), 57 (43), 55 (41), 45 (69), 43 (34), 41 (71).

4.2.2.2. 1-Cyclopentyl-3,3-dimethylbutan-2-ol (5b). R_f 0.4 (hexane/ethyl acetate: 8/2); ν (film) 3329 cm^{-1} (OH); δ_H 0.88 (s, 9H, 3×CH_3), 1.15 (m, 2H, CH_2), 1.38 (m, 2H, CH_2), 1.58 (m, 4H, 2×CH_2), 1.82 (m, 2H, CH_2), 2.00 (m, 1H, CHCH_2CHOH), 3.24 (dd, J=9.6 Hz, 2.3, 1H, CHOH); δ_C 24.9, 25.1 (2×CH_2), 25.6 (3×CH_3), 31.9, 33.7 (2×CH_2), 34.8 [$C(CH_3)_3$], 37.2 (CH_2CH_2CH), 37.8 (CH_2), 79.0 (CHOH); m/z 155 (M^+−15, 0.3%), 152 (M^+−18, 0.6%), 113 (30), 112 (18), 96 (15), 95 (100), 87 (27), 83 (11), 81 (11), 70 (14), 69 (58), 68 (10), 67 (31), 57 (41), 56 (16), 55 (30), 45 (40), 43 (32), 42 (11), 41 (74). HRMS: M^+−[H_2O], found 152.1583. $C_{11}H_{20}$ requires 152.1565.

4.2.2.3. 2-Cyclopentyl-1-phenyl-1-ethanol (5c).[50] R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3354 (OH), 3093, 3085, 3062, 3028 cm^{-1} (C=C); δ_H 1.54 (m, 11H, cycle and CH_2), 1.96 (s, 1H, OH), 4.67 (def. t, J=6.4 Hz, 1H, CHOH), 7.28 (m, 5H, ArH); δ_C 24.9, 25.0, 32.6, 32.9 (4×CH_2), 36.7 ($CHCH_2CHOH$), 45.5 (CH_2CHOH), 74.1 (CHOH), 125.9,

127.4, 128.4, 145.1 (6C, ArC); *m/z* 191 (M^++1, 0.7%), 190 (M^+, 5%), 108 (12), 107 (100), 104 (12), 79 (55), 77 (31), 51 (11), 41 (24).

4.2.2.4. 1-(Cyclopentylmethyl)cyclohexanol (5d). R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3415 cm^{-1} (OH); δ_H 1.29 (m, 20H, 2 cycles and OH), 1.80 (m, 2H, CH_2COH); δ_C 22.2, 25.0, 25.8, 34.6 (7C, 7×CH_2), 35.2 (CH), 38.0, 48.6 (3C, 3×CH_2), 71.8 (COH); *m/z* 183 (M^++1, 0.1%), 182 (M^+, 0.9%), 164 (13), 115 (16), 99 (100), 98 (14), 97 (27), 96 (21), 95 (11), 83 (22), 82 (29), 81 (84), 80 (10), 79 (27), 71 (24), 69 (26), 68 (18), 67 (47), 59 (16), 58 (22), 57 (12), 55 (84), 54 (11), 53 (18), 43 (38), 42 (15), 41 (83). HRMS: M^+, found 182.1668. $C_{12}H_{22}O$ requires 182.1671.

4.2.2.5. 1-Cyclopentyl-2-phenylpropan-2-ol (5e). R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3449 (OH), 3086, 3059, 3026, 1602, 1494 cm^{-1} (C=C); δ_H 1.02 (m, 2H, CH_2), 1.50 (m, 8H, CH_3, CH and 2×CH_2), 1.81 (m, 5H, 2×CH_2 and OH), 7.32 (m, 5H, ArH); δ_C 24.8, 24.9 (2×CH_2), 30.9 (CH_3), 34.1 (2×CH_2), 36.2 (C*H*CH_2), 50.3 (CH_2COH), 75.1 (COH), 124.8, 126.3, 128.0, 148.4 (6C, ArC); *m/z* 205 (M^++1, 0.2%), 204 (M^+, 1%), 122 (14), 121 (100), 118 (46), 117 (13), 105 (11), 91 (13), 78 (10), 77 (19), 51 (12), 43 (84), 41 (40). HRMS: M^+, found 204.1560. $C_{14}H_{20}O$ requires 204.1560.

4.3. DTBB-catalysed lithiation of 6-chloro-2-propylhex-1-ene (6)

4.3.1. Preparation of compound 6. *Preparation of 8-chlorooctan-4-one*.[28] To a solution of *n*-propylmagnesium chloride (2.0 M in diethyl ether, 15 mL, 30 mmol) in dry diethyl ether (15 mL) under argon atmosphere was added 5-chlorovaleronitrile (3.5 mL, 30 mmol), dropwise, via syringe. The reaction mixture was stirred at room temperature for 2 h. The reaction vessel was cooled on an ice bath, and ice was added in portions to the reaction mixture. Then the reaction mixture was acidified with 2 M HCl and extracted with diethyl ether (3×30 mL). The combined ether layers were washed (brine, 3×15 mL), dried over anhydrous magnesium sulphate, filtered and concentrated under vacuum (15 Torr) to afford a yellow oil. The crude oil was purified by column chromatography (silica gel, hexane/ethyl acetate mixtures), giving the title compound in 55% yield (2.66 g, 16.4 mmol).

4.3.1.1. 8-Chlorooctan-4-one.[28] R_f 0.2 (hexane/ethyl acetate: 9/1); ν (film) 1713 cm^{-1} (C=O); δ_H 0.92 (t, *J*=7.3 Hz, 3H, CH_3), 1.60 (q, *J*=7.3 Hz, 2H, C$H_2$$CH_3$), 1.76 (m, 4H, ClC$H_2CH_2CH_2$), 2.42 (m, 4H, C$H_2COCH_2$), 3.54 (t, *J*=6.1 Hz, 2H, $ClCH_2$); δ_C 13.6 (CH_3), 17.2, 20.9, 31.9, 41.6, 44.5 (5×CH_2), 44.6 (CO*C*$H_2$$CH_2$$CH_3$), 210.4 (C=O); *m/z* 164 (M^++2, 0.8), 162 (M^+, 2.5), 126 (14), 119 (28), 93 (11), 91 (34), 71 (100), 58 (12), 55 (69).

Preparation of 6-chloro-2-propylhex-1-ene.[27] To a mixture of methyltriphenylphosphonium bromide (8.80 g, 24.6 mmol) and sodium amide (1.26 g, 30.6 mmol) was added dry THF (10 mL) under an argon atmosphere and the mixture was stirred 15–20 min. A yellow salt was formed and a solution of 8-chlorooctan-4-one (2.66 g, 16.4 mmol) in dry THF (15 mL) was added. The reaction mixture was stirred for 2 h, the reaction medium developing during this period a tan colour. Finally, the reaction was hydrolysed with 15% NaOH (15 mL) and extracted with diethyl ether (3×20 mL). The organic phase was dried over anhydrous magnesium sulphate and concentrated under vacuum (15 Torr). The resulting oil was purified by simple distillation and 6-chloro-2-propylhex-1-ene was isolated with 60% yield (1.567 g, 9.8 mmol).

4.3.1.2. 6-Chloro-2-propylhex-1-ene (6). R_f 0.7 (hexane); ν (film) 3076, 1644 cm^{-1} (C=C); δ_H 0.90 (t, *J*=7.3 Hz, 3H, CH_3), 1.45 (m, 2H, CH_2), 1.59 (m, 2H, CH_2), 1.78 (m, 2H, CH_2), 2.01 (m, 4H, CH_2=C(CH_2)$_2$), 3.55 (t, *J*=6.4 Hz, 2H, CH_2Cl), 4.72 (s, 2H, CH_2=); δ_C 13.8 (CH_3), 20.8, 24.9, 32.2, 35.1, 38.0 (5×CH_2), 45.0 (CH_2Cl), 109.2 (*C*H_2=C), 149.0 (CH_2=*C*); *m/z* 162 (M^++2, 3.83%), 160 (M^+, 11.87%), 84 (31), 81 (11), 69 (34), 67 (13), 56 (100), 55 (54), 53 (12). HRMS: M^+, found 160.1036. $C_9H_{17}Cl$ requires 160.1019.

4.3.2. Lithiation of compound 6. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (13.3 mg, 0.05 mmol) in THF (4 mL) at −78°C was added 6-chloro-2-propylhex-1-ene (**6**; 0.080 g, 0.5 mmol) under an argon atmosphere. The colour disappeared after the substrate addition, the reaction mixture was stirred until the green colour was recovered (ca. 40 min) and the corresponding electrophile (0.55 mmol) was then added. The resulting mixture was stirred for 15 min at the same temperature (−78°C), then was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature for 10 min. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and was concentrated under vacuum (15 Torr). Compounds **8** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in Table 3; physical, spectroscopic and analytical data follows.

4.3.2.1. 3-Ethyl-8-propylnon-8-en-3-ol (8a). R_f 0.4 (hexane/ethyl acetate: 8/2); ν (film) 3401 (OH), 3077, 1644 cm^{-1} (C=C); δ_H 0.87 (m, 9H, 3×CH_3), 1.34 (m, 13H, 6×CH_2 and OH), 2.01 [m, 4H, CH_2C(=CH_2)CH_2], 4.70 (s, 2H, =CH_2); δ_C 7.7 (2×COHCH_2*C*H_3), 13.8 (CH_3), 20.8, 23.1, 28.4, 31.0, 35.9, 38.0, 38.1 (8×CH_2), 74.5 (COH), 108.7 (*C*H_2=C), 149.7 (CH_2=*C*); *m/z* 194 (M^+−18, 0.45%), 165 (19), 123 (14), 110 (54), 109 (18), 97 (13), 95 (32), 87 (100), 85 (15), 83 (12), 81 (20), 69 (39), 67 (13), 57 (68), 55 (35). HRMS: M^+−[H_2O], found 194.2058. $C_{14}H_{25}$ requires 194.2035.

4.3.2.2. 2,2-Dimethyl-8-propylnon-8-en-3-ol (8b). R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3383 (OH), 3072, 1644 cm^{-1} (C=C); δ_H 0.90 [m, 12H, CH_2*C*H_3 and C(*C*H_3)$_3$], 1.37 (m, 9H, 4×CH_2 and OH), 2.00 [q, *J*=8.2 Hz, 4H, CH_2C(=CH_2)CH_2], 3.18 (d, *J*=9.9 Hz, 1H, C*H*OH), 4.70 (s, 2H, CH_2=); δ_C 13.8 (CH_2*C*H_3), 20.8, 26.9, 27.8, 31.3, 36.0, 38.1 (6×CH_2), 25.6 [3C, C(*C*H_3)$_3$], 34.9 [*C*(CH_3)$_3$], 79.9 (CHOH), 108.6 (CH_2=), 149.8 (C=); *m/z* 213 (M^++1, 0.04%), 212 (M^+, 0.14%), 137 (19), 123 (10), 110 (61), 97 (12), 96 (14), 95 (100), 87 (14), 83 (11), 81 (57), 71 (14), 70 (10), 69 (41), 68 (11), 67 (26), 57 (54), 56 (18), 55 (48). HRMS: M^+−[H_2O], found 194.2043. $C_{14}H_{26}$ requires 194.2035.

4.3.2.3. 1-Phenyl-6-propylhept-6-en-1-ol (8c). R_f 0.2 (hexane/ethyl acetate: 9/1); ν (film) 3362 (OH), 3082, 3065, 3029, 1644 cm^{-1} (C=C); δ_H 0.88 (t, *J*=7.3 Hz, 3H, CH_3), 1.35 (m, 6H, 3×CH_2), 1.73 (m, 2H, CH_2), 1.95 [def. t, *J*=7.0 Hz, 4H, CH_2C(=CH_2)CH_2], 2.28 (s, 1H, OH), 4.60 (t,

J=6.6 Hz, 1H, C*H*OH), 4.68 (s, 2H, CH_2=), 7.29 (m, 5H, ArH); δ_C 13.8 (CH_3), 20.8, 25.5, 27.6, 35.8, 38.1, 38.9 (6×CH_2), 74.5 (CHOH), 108.6 (CH_2=), 125.8, 127.3, 128.3, 144.8 (6C, ArC), 149.7 (*C*=CH_2); *m/z* 232 (M^+, 0.1%), 214 (M^+-18, 3.6%), 133 (13), 130 (32), 117 (10), 110 (24), 107 (100), 105 (12), 91 (11), 79 (56), 77 (28), 55 (19). HRMS: M^+, found 232.1834. $C_{16}H_{24}O$ requires 232.1827.

4.3.2.4. 1-(5-Propylhex-5-enyl)cyclohexanol (8d). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3385 (OH), 3076, 1644 cm^{-1} (C=C); δ_H 0.90 (t, J=7.3 Hz, 3H, CH_3), 1.43 (m, 19H, 9×CH_2 and OH), 2.00 [m, 4H, C*H*$_2$C(=CH_2)-C*H*$_2$], 4.69 (s, 2H, CH_2=); δ_C 13.8 (CH_3), 20.8, 22.2, 22.6, 25.8, 28.3, 36.0, 37.3, 38.1, 42.3 (11×CH_2), 71.3 (COH), 108.6 (CH_2=), 149.7 (C=); *m/z* 206 (M^+-18, 1.8%), 135 (12), 123 (18), 122 (52), 111 (11), 110 (94), 109 (18), 108 (10), 107 (18), 99 (89), 97 (10), 96 (11), 95 (100), 94 (13), 93 (21), 83 (17), 82 (14), 81 (84), 80 (10), 79 (33), 69 (27), 68 (14), 67 (41), 57 (11), 56 (14), 55 (75), 53 (16). HRMS: $M^+-[H_2O]$, found 206.2039. $C_{15}H_{26}$ requires 206.2035.

4.3.2.5. 2-Phenyl-7-propyloct-7-en-2-ol (8e). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3416 (OH), 3083, 3064, 3026, 1644 cm^{-1} (C=C); δ_H 0.87 (t, J=7.3 Hz, 3H, CH_2CH_3), 1.28 (m, 7H, 3×CH_2 and OH), 1.54 (s, 3H, COHC*H*$_3$), 1.81 (m, 2H, CH_2), 1.93 [t, J=7.41 Hz, 4H, C*H*$_2$C(=CH_2)C*H*$_2$], 4.64 (s, 2H, CH_2=), 7.22, 7.32, 7.42 (3m, 5H, ArH); δ_C 13.8 (CH_3), 20.8, 23.7, 28.1, 35.8, 38.1, 44.0 (6×CH_2), 30.4 (*C*H$_3$COH), 74.6 (COH), 108.6 (CH_2=), 124.7, 126.4, 128.0, 148.0 (6C, ArC), 149.7 (C=); *m/z* 246 (M^+, 0.03%), 228 (M^+-18, 2.0%), 144 (33), 131 (25), 129 (56), 121 (100), 118 (28), 117 (16), 115 (14), 105 (16), 91 (22), 77 (11), 55 (13). HRMS: M^+, found 246.2011. $C_{17}H_{26}O$ requires 246.1984.

4.3.2.6. Trimethyl(5-propylhex-5-enyl)silane (8f). R_f 0.8 (hexane); ν (film) 3071, 1644 cm^{-1} (C=C); δ_H 0.00 [s, 9H, Si(C*H*$_3$)$_3$], 0.52 (t, J=8.3 Hz, 2H, CH_2Si), 0.93 (t, J=7.3 Hz, 3H, CH_3), 1.32 (m, 2H, CH_2), 1.46 (m, 4H, 2×CH_2), 2.00 [m, 4H, C*H*$_2$C(=CH_2)C*H*$_2$], 4.72 (s, 2H, CH_2=C); δ_C −1.65 [3C, Si(C*H*$_3$)$_3$], 13.9 (CH_3), 16.6, 20.9, 23.7, 31.7 (4×CH_2), 35.8, 38.2 [C*H*$_2$C(=CH_2)C*H*$_2$], 108.5 (CH_2=), 150.1 (*C*=CH_2); *m/z* 198 (M^+, 0.03%), 114 (25), 73 (100), 59 (17). HRMS: $M^+-[CH_3]$, found 183.1572. $C_{11}H_{23}Si$ requires 183.1569.

4.4. DTBB-catalysed lithiation of (*Z*)-8-chloro-3-octene (9)

4.4.1. Preparation of compound 9.[29] A mixture of (*Z*)-5-octen-1-ol (15.4 mL, 100 mmol) and triphenylphospane (28.87 g, 110 mmol) in carbon tetrachloride was refluxed for 48 h. Then, the reaction mixture was concentrated under vacuum (15 Torr) and the residue was purified by column chromatography (silica gel, hexane) to give 14.7 g of compound **9** (99%).

4.4.1.1. (*Z*)-8-Chlorooct-3-ene (9).[51] R_f 0.7 (hexane); ν (film) 3005, 1655 cm^{-1} (C=C); δ_H 0.96 (t, J=7.5 Hz, 3H, CH_3), 1.49 (m, 2H, CH_2), 1.78 (m, 2H, CH_2), 2.04 (m, 4H, C*H*$_2$CH=CHC*H*$_2$), 3.53 (t, J=6.6 Hz, 2H, CH_2Cl), 5.35 (m, 2H, CH=CH); δ_C 14.3 (CH_3), 20.5, 26.2, 26.9, 32.1 (4×CH_2), 44.9 (CH_2Cl), 128.2 (=*C*HCH$_2$CH$_2$), 132.2 (=*C*HCH$_2$CH$_3$); *m/z* 148 (M^++2, 9.4%), 146 (M^+, 29.2%), 104 (26), 91 (10), 81 (36), 70 (13), 69 (53), 68 (37), 67 (30), 56 (45), 55 (100), 54 (16), 53 (19).

4.4.2. Lithiation of compound 9. To a stirred green suspension of lithium powder (40 mg, 5.8 mmol) and DTBB (26.6 mg, 0.1 mmol) in THF (4 mL) at −78°C was added (*Z*)-8-chlorooct-3-ene (**9**; 0.146 g, 1.0 mmol) under an argon atmosphere. The colour disappeared after the substrate addition, the reaction mixture was stirred until the green colour was recovered (ca. 40 min) and the corresponding electrophile (1.1 mmol) was then added. The resulting mixture was stirred for 15 min at the same temperature (−78°C), then it was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature for 10 min. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and the solvents were concentrated under vacuum (15 Torr). Compounds **11** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in Table 4; physical, spectroscopic and analytical data follows.

4.4.2.1. (*Z*)-3-Ethylundec-8-en-3-ol (11a). R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3415 (OH), 3005 cm^{-1} (C=C); δ_H 0.86 (t, J=7.6 Hz, 6H, 2×COHCH$_2$C*H*$_3$), 0.96 (t, J=7.5 Hz, 3H, CHCH$_2$C*H*$_3$), 1.31 (m, 7H, CH$_2$CH$_2$CH$_2$COH), 1.46 (q, J=7.5 Hz, 4H, 2×C*H*$_2$CH$_3$), 2.04 (m, 4H, C*H*$_2$CH=CHC*H*$_2$), 5.35 (m, 2H, CH=CH); δ_C 7.7 (2×CH_2*C*H$_3$), 14.3 (CH_3), 20.5, 23.0, 27.0, 30.4, 30.9, 38.1 (7×CH_2), 74.6 (COH), 129.0 (=*C*HCH$_2$CH$_2$), 131.7 (=*C*HCH$_2$CH$_3$); *m/z* 180 (M^+-18, 1.1%), 169 (15), 151 (17), 110 (19), 109 (14), 97 (13), 96 (10), 95 (23), 87 (93), 85 (12), 82 (14), 81 (17), 69 (23), 67 (19), 57 (100), 55 (39). HRMS: $M^+-[H_2O]$, found 180.1868. $C_{13}H_{24}$ requires 180.1878.

4.4.2.2. (*Z*)-2,2-Dimethylundec-8-en-3-ol (11b). R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3393 (OH), 3005, 1463 cm^{-1} (C=C); δ_H 0.89 (s, 9H, C(C*H*$_3$)$_3$), 1.91 (t, J=7.5 Hz, 3H, CH_3), 1.39 (m, 7H, 3×CH_2 and OH), 2.04 (m, 4H, C*H*$_2$CH=CHC*H*$_2$), 3.18 (dd, J=10.2 Hz, 1.5, 1H, C*H*OH), 5.35 (m, 2H, CH=CH); δ_C 14.3 (CH_3), 20.4, 26.6, 27.0, 29.7, 31.3 (5×CH_2), 25.6 [3C, C(*C*H$_3$)$_3$], 34.8 [*C*(CH$_3$)$_3$], 79.8 (CHOH), 129.0 (=*C*HCH$_2$CH$_2$), 131.5 (=*C*HCH$_2$CH$_3$); *m/z* 180 (M^+-18, 3.1%), 141 (12), 137 (15), 124 (14), 123 (26), 110 (31), 109 (22), 97 (15), 96 (22), 95 (29), 87 (20), 85 (10), 83 (19), 82 (49), 81 (100), 71 (25), 70 (15), 69 (39), 68 (14), 67 (69), 57 (82), 56 (12), 55 (75), 54 (12), 53 (11). HRMS: $M^+-[H_2O]$, found 180.1876. $C_{13}H_{24}$ requires 180.1878.

4.4.2.3. (*Z*)-1-Phenylnon-6-en-1-ol (11c). R_f 0.2 (hexane/ethyl acetate: 9/1); ν (film) 3371 (OH), 3085, 3062, 3027, 3003, 1602, 1493 cm^{-1} (C=C); δ_H 0.93 (t, J=7.6 Hz, 3H, CH_3), 1.33 (m, 4H, 2×CH_2), 1.72 (m, 2H, CH_2), 2.01 (m, 4H, C*H*$_2$CH=CHC*H*$_2$), 2.34 (s, 1H, OH), 4.61 (t, J=6.6 Hz, 1H, C*H*OH), 5.33 (m, 2H, CH=CH), 7.29 (m, 5H, ArH); δ_C 14.3 (CH_3), 20.4, 25.4, 26.9, 29.6, 38.9 (5×CH_2), 74.6 (CHOH), 125.8, 127.4, 128.3, 144.8 (6C, ArC), 128.9 (=*C*HCH$_2$CH$_2$), 131.7 (=*C*HCH$_2$CH$_3$); *m/z* 219 (M^++1, 0.20%), 218 (M^+, 1.22%), 144 (15), 133 (15), 130 (12), 117 (11), 107 (100), 105 (13), 104 (12), 91 (11), 79 (52), 77 (25). HRMS: M^+, found 218.1658. $C_{15}H_{22}O$ requires 218.1671.

4.4.2.4. 1-[(*Z*)-Oct-5-enyl]-1-cyclohexanol (11d). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3383 (OH), 3004, 1462 cm^{-1} (C=C); δ_H 0.96 (t, J=7.5 Hz, 3H, CH_3), 1.50 (m, 17H, 8×CH_2 and OH), 2.04 (m, 4H, C*H*$_2$CH=CHC*H*$_2$), 5.35 (m, 2H, CH=CH); δ_C 14.3 (CH_3), 20.4, 22.2, 22.5, 25.8, 27.0, 30.3, 37.3, 42.2 (10×CH_2), 71.4 (COH), 129.0

(=*C*HCH$_2$CH$_2$), 131.6 (=*C*HCH$_2$CH$_3$); *m/z* 192 (M$^+$−18, 4.53%), 149 (17), 135 (13), 111 (14), 110 (17), 109 (14), 99 (100), 96 (19), 95 (12), 83 (11), 82 (20), 81 (69), 79 (16), 69 (17), 67 (29), 55 (22). HRMS: M$^+$−[H$_2$O], found 192.1889. $C_{14}H_{24}$ requires 192.1878.

4.4.2.5. (*Z*)-2-Phenyldec-7-en-2-ol (11e). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3435 (OH), 3086, 3060, 3024, 3003, 1602, 1494, 1462 cm^{-1} (C=C); δ_H 0.92 (t, *J*=7.5 Hz, 3H, C*H*$_3$CH$_2$), 1.22 (m, 4H, 2×CH$_2$), 1.55 (s, 3H, C*H*$_3$COH), 1.79 (m, 3H, CH$_2$COH), 1.98 (m, 4H, C*H*$_2$CH=CHC*H*$_2$), 5.29 (m, 2H, CH=CH), 7.23, 7.33, 7.43 (3m, 5H, ArH); δ_C 14.3 (*C*H$_3$CH$_2$), 20.4, 23.6, 26.9, 30.0, 44.1 (5×CH$_2$), 30.03 (*C*H$_3$COH), 74.7 (COH), 124.7, 126.4, 128.1, 148.0 (6C, ArC), 128.9 (=*C*HCH$_2$CH$_2$), 131.6 (=*C*HCH$_2$CH$_3$); *m/z* 232 (M$^+$, 0.05%), 121 (100), 105 (12). HRMS: M$^+$, found 232.1874. $C_{16}H_{24}O$ requires 232.1827.

4.4.2.6. Trimethyl-[(*Z*)-oct-5-enyl]silane (11f). R_f 0.8 (hexane); ν (film) 3005, 1462 cm^{-1} (C=C); δ_H −0.03 [s, 9H, Si(CH$_3$)$_3$], 0.49 (m, 2H, CH$_2$Si), 0.96 (t, *J*=7.5 Hz, 3H, CH$_3$), 1.32 (m, 4H, 2×CH$_2$), 2.04 (m, 4H, C*H*$_2$CH=CHC*H*$_2$), 5.35 (m, 2H, CH=CH); δ_C −1.7 [3C, Si(CH$_3$)$_3$], 14.4 (CH$_3$), 16.6, 20.5, 23.6, 26.8, 33.7 (5×CH$_2$), 129.2 (=*C*HCH$_2$CH$_2$), 131.5 (=*C*HCH$_2$CH$_3$); *m/z* 185 (M$^+$+1, 0.09%), 184 (M$^+$, 0.56%), 99 (11), 73 (100), 59 (17). HRMS: M$^+$, found 184.1657. $C_{11}H_{24}Si$ requires 184.1647.

4.5. DTBB-catalysed lithiation of 6-chloro-2-phenylhex-1-ene (12)

4.5.1. Preparation of compound 12.[31] To a solution of α-bromostyrene (3.0 mL, 20.7 mmol) in dry THF (45 mL) at −78°C was slowly added *n*-BuLi (13.0 mL of a solution 1.6 M in hexane, 20.8 mmol), and the mixture was stirred for 1 h at the same temperature (−78°C). Then 1-chloro-4-iodobutane (2.5 mL, 20.0 mmol) was added and the solution was allowed to warm to room temperature. After 4 h stirring at room temperature the reaction mixture was hydrolysed with H$_2$O (40 mL) and extracted with ethyl acetate (3×25 mL). The organic layer was dried with anhydrous magnesium sulphate and was concentrated under vacuum (15 Torr). The crude oil was purified by column chromatography (silica gel, hexane) to give 2.13 g (53%) of the title compound.

4.5.1.1. 6-Chloro-2-phenylhex-1-ene (12). R_f 0.5 (hexane); ν (film) 3081, 3056, 3024, 1600, 1494 cm^{-1} (C=C); δ_H 1.59 (m, 2H, CH$_2$), 1.79 (m, 2H, CH$_2$), 2.53 (m, 2H, C*H*$_2$C=CH$_2$), 3.50 (t, *J*=6.6 Hz, 2H, CH$_2$Cl), 5.06 (d, *J*=1.4 Hz, 1H, C=CH*H*), 5.28 (d, *J*=1.4 Hz, 1H, C=C*H*H), 7.30 (m, 5H, ArH); δ_C 25.3, 32.1 (2×CH$_2$), 34.5 (CH$_2$=C*C*H$_2$), 44.8 (CH$_2$Cl), 112.6 (*C*H$_2$=C), 126.0, 127.4, 128.3, 140.9 (6C, ArC), 147.8 (CH$_2$=*C*); *m/z* 196 (M$^+$+2, 1.2%), 194 (M$^+$, 3.9%), 131 (13), 119 (10), 118 (100), 117 (29), 115 (18), 103 (13), 91 (17), 77 (10). HRMS: M$^+$, found 194.0872. $C_{12}H_{15}Cl$ requires 194.0862.

4.5.2. Lithiation of compound 12. To a stirred green suspension of lithium powder (45 mg, 6.5 mmol) and DTBB (13.3 mg, 0.05 mmol) in THF (4 mL) at −78°C was added 6-chloro-2-phenylhex-1-ene (**12**; 0.097 g, 0.5 mmol) under an argon atmosphere. The colour disappeared after the substrate addition, the reaction mixture was then stirred until the green colour was recovered (ca. 30 min) and the corresponding electrophile (0.55 mmol) was added. The resulting mixture was stirred for 15 min at the same temperature (−78°C), then it was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature for 10 min. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and was concentrated under vacuum (15 Torr). Compounds **14** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in Table 5; physical, spectroscopic and analytical data follows.

4.5.2.1. 3-[(1-Phenylcyclopentyl)methyl]pentan-3-ol (14a). R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3591, 3585, 3485 (OH), 3085, 3057, 3022, 1600 cm^{-1} (C=C); δ_H 0.69 (t, *J*=7.4 Hz, 6H, 2×CH$_3$), 1.27 (q, *J*=7.5 Hz, 4H, 2×C*H*$_2$CH$_3$), 1.67 (m, 6H, 3×CH$_2$), 1.99 (s, 2H, CC*H*$_2$COH), 2.18 (m, 2H, CH$_2$), 7.17 (t, *J*=7.3 Hz, 1H, ArH), 7.33 (m, 2H, 2×ArH), 7.42 (d, *J*=1.38 Hz, 2H, 2×ArH); δ_C 7.9 (2×CH$_3$), 22.5, 31.7, 40.1 (6×CH$_2$), 49.7 (C*C*H$_2$COH), 50.2 (*C*CH$_2$COH), 76.1 (COH), 125.8, 127.1, 128.2, 147.1 (6×ArC); *m/z* 228 (M$^+$−18, 0.14%), 146 (12), 145 (100), 91 (50), 87 (46). HRMS: M$^+$−[H$_2$O], found 228.1903. $C_{17}H_{24}$ requires 228.1878.

4.5.2.2. 3,3-Dimethyl-1-(1-phenylcyclopentyl)butan-2-ol (14b). R_f 0.2 (hexane/ethyl acetate: 9/1); ν (film) 3584, 3500 (OH), 3084, 3057, 3023, 1600, 1495 cm^{-1} (C=C); δ_H 0.76 (s, 9H, 3×CH$_3$), 1.79 (m, 11H, 5×CH$_2$ and OH), 3.08 (dd, *J*=8.8 Hz, 0.8, 1H, C*H*OH), 7.26 (m, 5H, ArH); δ_C 22.7, 23.0, 36.9, 39.0 (4×CH$_2$), 25.5 (3×CH$_3$), 34.8 [*C*(CH$_3$)$_3$], 44.0 (*C*H$_2$CHOH), 50.3 (*C*CH$_2$), 77.2 (CHOH), 125.9, 126.9, 128.4, 148.2 (6C, ArC); *m/z* 247 (M$^+$+1, 0.11%), 246 (M$^+$, 0.59%), 146 (36), 145 (100), 91 (35). HRMS: M$^+$, found 246.1974. $C_{17}H_{26}O$ requires 246.1984.

4.5.2.3. 1-Phenyl-2-(1-phenylcyclopentyl)ethanol (14c). R_f 0.2 (hexane/ethyl acetate: 9/1); ν (film) 3417 (OH), 3083, 3058, 3026 1600, 1494 cm^{-1} (C=C); δ_H 1.30 (m, 4H, 2×CH$_2$), 1.69 (m, 4H, 2×CH$_2$), 2.05 (m, 3H, CH$_2$ and OH), 4.44 (dd, *J*=8.3 Hz, 7.8, 1H, C*H*OH), 7.27 (m, 10H, 2×ArH); δ_C 22.7, 22.9, 37.7, 38.9 (CH$_2$ of the cyclopentyl), 50.4 (*C*CH$_2$), 51.4 (*C*H$_2$COH), 72.5 (CHOH), 125.6, 125.9, 126.9, 127.1, 128.3, 128.4, 145.6, 147.7 (10×ArC); *m/z* 266 (M$^+$, 0.21%), 147 (12), 146 (100), 145 (31), 129 (11), 117 (15), 115 (15), 107 (63), 104 (11), 91 (64), 79 (32), 77 (25). HRMS: M$^+$, found 266.1646. $C_{19}H_{22}O$ requires 266.1671.

4.6. DTBB-catalysed lithiation of (*Z*)-6-chloro-1-phenylhex-1-ene (15)

4.6.1. Preparation of compound 15. *Preparation of 6-chloro-1-phenylhex-1-yne.*[32] To a solution of PdCl$_2$(PPh$_3$)$_2$ (3.5 mg, 0.005 mmol) and CuI (1.9 mg, 0.01 mmol) in dry THF (3 mL) were successively added iodobenzene (0.056 mL, 0.5 mmol), 6-chlorohex-1-yne (0.074 mL, 0.6 mmol) and tetrabutylamonium fluoride (TBAF; 1 mL of solution 1.0 M in THF, 1 mmol) under an argon atmosphere. The reaction mixture was stirred for 3 h at room temperature and then was passed through a Celite pad. The filtrate was concentrated under vacuum and subjected to column chromatography on silica gel (hexane/ethyl acetate) to give 0.094 g (98%) of the title compound.

4.6.1.1. 6-Chloro-1-phenylhex-1-yne.[52] R_f 0.3 (hexane);

ν (film) 3056, 1598, 1489 cm^{-1} (C=C); δ_H 1.75 (m, 2H, CH_2), 1.95 (m, 2H, CH_2), 2.45 (t, J=6.7 Hz, 2H, C≡CCH_2), 3.59 (t, J=6.7 Hz, 2H, CH_2Cl), 7.26, 7.38 (2m, 5H, ArH); δ_C 18.7, 25.8, 31.6 (3×CH_2), 44.5 (CH_2Cl), 81.1 (PhC≡C), 89.2 (PhC≡C), 123.7, 127.6, 128.2, 131.5 (6×ArC); *m/z* 194 (M^++2, 4.4%), 193 (M^++1, 1.9%), 192 (M^+, 13.5%), 156 (14), 143 (15), 130 (21), 129 (40), 128 (41), 127 (12), 117 (40), 116 (13), 115 (100), 102 (11), 91 (24), 89 (12), 63 (11).

Preparation of (Z)-6-chloro-1-phenylhex-1-ene.[33] A mixture of 6-chloro-1-phenylhex-1-yne (0.46 g, 2.4 mmol) and the Lindlar catalyst (0.24 g) in ethanol (13 mL), containing 3 drops of quinoline was hydrogenated at atmospheric pressure for 16 h. Then, the suspension was filtered through a Celite pad and it was washed with ethanol. The ethanol was concentrated (15 Torr) and the residue was diluted in diethyl ether and was washed with diluted 1 M HCl and water. The organic phase was dried over anhydrous magnesium sulphate and the solvent was concentrated under vacuum (15 Torr) to give 0.44 g (95%) of the title compound.

4.6.1.2. (*Z*)-6-Chloro-1-phenylhex-1-ene (15).[53] R_f 0.5 (hexane); ν (film) 3080, 3055, 3023, 3008, 1643 cm^{-1} (C=C); δ_H 1.59 (m, 2H, CH_2), 1.79 (m, 2H, CH_2), 2.35 (m, 2H, =CHCH_2), 3.50 (t, J=6.6 Hz, 2H, CH_2Cl), 5.63 (m, 1H, =C*H*CH_2), 6.44 (d, J=11.7 Hz, 1H, PhC*H*), 7.27 (m, 5H, ArH); δ_C 27.0, 27.7 (2×CH_2), 32.1 (=CH*C*H_2), 44.8 (CH_2Cl), 126.5, 128.1, 128.7, 129.4, 132.0, 137.5 (8C, ArC and CH=CH); *m/z* 196 (M^++2, 4.36%), 195 (M^++1, 1.53%), 194 (M^+, 12.26%), 118 (10), 117 (100), 116 (10), 115 (34), 104 (21), 91 (30).

4.6.2. Lithiation of compound 15. To a stirred green suspension of lithium powder (35 mg, 5.0 mmol) and DTBB (6 mg, 0.02 mmol) in THF (4 mL) at −30°C was added 6-chloro-1-phenylhex-1-ene (**15**; 0.050 g, 0.2 mmol) and the corresponding electrophile in THF (1.5 mL) under an argon atmosphere. The reaction was finished in 30 min (the solution recovered the green colour) and then it was hydrolysed with 2 M HCl (5 mL) at the same temperature (−30°C), and then it was stirred for 10 min allowing the temperature to rise to room temperature. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and was concentrated under vacuum (15 Torr). Compounds **17** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in Table 5; physical, spectroscopic and analytical data follows.

4.6.2.1. 3-Cyclopentyl(phenyl)methylpentan-3-ol (17a). R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3584, 3493 (OH), 3084, 3059, 3023 1602, 1494 cm^{-1} (C=C); δ_H 0.80 (t, J=7.4 Hz, 3H, CH_3), 0.88 (t, J=7.4 Hz, 3H, CH_3), 1.31 (m, 12H, OH, 5×CH_2 and C*H*H), 1.97 (m, 1H, CH*H*), 2.32 (m, 1H, C*H*CH_2), 2.68 (d, J=7.8 Hz, 1H, C*H*COH), 7.23 (m, 5H, ArH); δ_C 7.8, 8.1 (2×CH_3), 24.2, 24.9, 29.3, 29.4, 32.4, 33.3 (6×CH_2), 41.0 (*C*HCH_2), 56.7 (*C*HCOH), 77.2 (COH), 126.0, 127.6, 130.3, 142.3 (6C, ArC); *m/z* 228 (M^+−18, 1.4%), 160 (49), 159 (20), 131 (12), 129 (11), 117 (27), 115 (15), 92 (75), 91 (53), 87 (100), 69 (19), 57 (12). HRMS: M^+−[H_2O], found 228.1865. $C_{17}H_{24}$ requires 228.1878.

4.6.2.2. 2-Cyclopentyl-1,2-diphenylethanol (17b). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3563, 3440 (OH), 3084, 3060, 3027, 1602, 1493 cm^{-1} (C=C); δ_H (mixture of diastereomers) 1.63 (m, 20H, 2×cycle and 2×OH), 2.69 (dd, J=9.6 Hz, 5.1, 1H, CHOHC*H*CH, first diastereomer), 2.92 (dd, J=9.8 Hz, 5.6, 1H, CHOHC*H*CH, second diastereomer), 5.04 (2d, J=5.6 Hz, 5.1, 2H, 2×C*H*OH), 7.00 (4m, 20H, ArH); δ_C (mixture of diastereomers) 24.5, 24.7, 25.0, 25.5, 31.2, 31.7, 31.8, 32.1 (8×CH_2), 41.2, 41.6 (2×*C*HCH_2), 58.8, 59.5 (2×*C*HCHCH_2), 76.1, 76.6 (CHOH), 126.18, 126.24, 126.4, 127.0, 127.1, 127.2, 127.4, 127.5, 127.8, 127.9, 129.7, 130.0, 139.7, 140.1, 142.0, 143.5 (24C, ArC); *m/z* 266 (M^+, 0.08%), 161 (12), 160 (100), 129 (10), 117 (19), 115 (18), 107 (84), 105 (12), 92 (72), 91 (87), 79 (37), 77 (27). HRMS: M^+−[H_2O], found 248.1559. $C_{19}H_{20}$ requires 248.1565.

4.6.2.3. Cyclopentyl(phenyl)methyl(trimethyl)silane (17c). R_f 0.7 (hexane); ν (film) 3081, 3060, 3022, 1600, 1495 cm^{-1} (C=C); δ_H −0.07 [s, 9H, Si(CH_3)$_3$], 1.29 (m, 7H, 3×CH_2 and CH*H*), 1.83 (d, J=11.2 Hz, 1H, CHSi), 1.93 (m, 1H, C*H*H), 2.31 (m, 1H, C*H*CHSi), 7.04, 7.21 (2m, 5H, ArH); δ_C −1.3 [3C, Si(CH_3)$_3$], 24.1, 25.5 (2×CH_2), 32.3, 34.3 (2×CH_2), 42.6, 43.8 (2×CH), 124.1, 127.9, 128.0, 145.5 (6C, ArC); *m/z* 233 (M^++1, 1.7%), 232 (M^+, 8.32%), 158 (56), 135 (12), 91 (14), 73 (100). HRMS: M^+, found 232.1647. $C_{15}H_{24}Si$ requires 232.1647.

4.7. DTBB-catalysed lithiation of 6-chlorononon-1-ene (18)

4.7.1. Preparation of compound 18. *Preparation of non-8-en-4-ol*. Magnesium powder (378 mg, 15.6 mmol) was warmed under vacuum for 20 min. Then, dry THF (33 mL) was added under an argon atmosphere. 5-Bromopent-1-ene (1.94 mL, 15.6 mmol) was dissolved in THF (7 mL) and a few drops of this solution were added at room temperature to start the reaction. The reaction mixture was then cooled to −15°C by means of an ice-salt bath. The rest of the solution of the mentioned bromide was added dropwise over 1.5 h using a syringe-pump. The resultant grey solution was stirred for 30 min and then butyraldehyde (1.38 mL, 15.6 mmol) was added dropwise and the reaction mixture was stirred overnight. The mixture was cooled in an ice bath and ice portions were added to hydrolyse the reaction. Then 2 M HCl was added to acidify the resulting mixture and it was extracted with diethyl ether (3×30 mL). The organic phase was dried with anhydrous magnesium sulphate, and concentrated under vacuum (15 Torr). The residue was purified by column chromatography (silica gel, hexane/ethyl acetate) to give 1.77 g (80%) of the title compound.

4.7.1.1. Non-8-en-4-ol.[54] R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3355 (OH), 3077, 1641 cm^{-1} (C=C); δ_H 0.93 (t, J=6.8 Hz, 3H, CH_3), 1.42 (m, 8H, 4×CH_2), 1.66 (s, 1H, OH), 2.06 (m, 2H, CH_2CH=CH_2), 3.59 (m, 1H, C*H*OH), 4.95 (d, J=11.7 Hz, 1H, =C*H*H), 5.01 (d, J=19.2 Hz, 1H, =CH*H*), 5.81 (m, 1H, C*H*=CH_2); δ_C 14.0 (CH_3), 18.8, 24.9, 33.7, 36.8, 39.6 (5×CH_2), 71.5 (CHOH), 114.5 (=CH_2), 138.7 (*C*H=CH_2); *m/z* 124 (M^+−18, 0.83%), 99 (18), 82 (17), 81 (69), 73 (26), 57 (23), 55 (100), 54 (25).

Preparation of 6-chlorononon-1-ene. A mixture of non-8-en-4-ol (2.77 g, 19.5 mmol) and triphenylphosphane (10.24 g, 39.0 mmol) in carbon tetrachloride (50 mL) was refluxed

for 48 h. Then, the reaction mixture was concentrated and the residue was purified by column chromatography (silica gel, hexane) to give 3.1 g (99%) of the title compound.

4.7.1.2. 6-Chlorononon-1-ene (18). R_f 0.8 (hexane); ν (film) 3078, 1641 cm^{-1} (C=C); δ_H 0.92 (t, J=7.3 Hz, 3H, CH_3), 1.52 (m, 4H, 2×CH_2), 1.74 (m, 4H, 2×CH_2), 2.07 (m, 2H, CH_2CH=CH_2), 3.91 (m, 1H, CHCl), 4.97 (d, J=11.7 Hz, 1H, =CHH), 5.02 (d, J=19.1 Hz, 1H, =CHH), 5.80 (m, 1H, CH=CH_2); δ_C 13.6 (CH_3), 19.7, 25.7, 33.2, 37.8, 40.6 (5×CH_2), 63.7 (CHCl), 114.8 (=CH_2), 138.3 (CH=CH_2); m/z 162 (M^++2, 0.18%), 160 (M^+, 0.5), 96 (31), 95 (35), 83 (16), 82 (53), 81 (49), 69 (35), 68 (37), 67 (51), 56 (24), 55 (89), 54 (100), 53 (22). HRMS: M^+, found 160.1020. $C_9H_{17}Cl$ requires 160.1019.

4.7.2. Lithiation of compound 18. Preparation of compounds 20. To a stirred green suspension of lithium powder (40 mg, 5.8 mmol) and DTBB (13.3 mg, 0.05 mmol) in THF (3 mL) at −78°C was added a mixture of 6-chlorononon-1-ene (**18**; 0.080 g, 0.5 mmol) and the corresponding electrophile (0.55 mmol) in THF (1 mL) under an argon atmosphere. When the addition finished the mixture was stirred for 30 additional minutes (the solution recovered the green colour), then it was hydrolysed with 2 M HCl (5 mL) at the same temperature (−78°C), and it was stirred allowing the temperature to rise to room temperature. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and then was concentrated under vacuum (15 Torr). Compounds **20** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in Table 7; physical, spectroscopic and analytical data follows.

4.7.2.1. 3-Ethyl-4-propylnon-8-en-3-ol (20a). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3493 (OH), 3076, 1641 cm^{-1} (C=C); δ_H (in benzene-d_6) 0.63 (s, 1H, OH), 0.80 (def. t, J=7.5 Hz, 6H, 2×COHCH$_2$CH_3), 0.91 (def. t, J=7.0 Hz, 3H, CH$_2$CH$_2$CH_3), 1.28 (m, 13H, CH, 6×CH_2), 2.02 (m, 2H, =CHCH_2), 5.04 (m, 2H, =CH_2), 5.81 (m, 1H, CH=); δ_C (in benzene-d_6) 7.8 (2×COHCH$_2$CH_3), 15.0 (CH$_2$CH$_2$CH_3), 23.0, 28.8, 29.3, 30.3, 33.2, 34.9 (7C, 7×CH_2), 44.7 (CH), 76.4 (COH), 114.6 (CH_2=), 139.2 (=CH); m/z 194 (M^+−18, 0.09%), 87 (100), 69 (17), 57 (48), 55 (20). HRMS: M^+−[CH_2CH_3], found 183.1767. $C_{12}H_{23}O$ requires 183.1749.

4.7.2.2. 2,2-Dimethyl-4-propylnon-8-en-3-ol (20b). R_f 0.5 (hexane/ethyl acetate: 9/1); ν (film) 3491 (OH), 3076, 1641 cm^{-1} (C=C); δ_H (mixture of diastereomers) 0.91 (m, 24H, 8×CH_3), 1.29 (m, 20H, 8×CH_2, 2×CH and 2×OH), 2.04 (m, 4H, 2×=CHCH_2), 3.23 (m, 2H, 2×CHOH), 4.94 (d, J=12.2 Hz, 2H, 2 ×=CHH), 5.00 (d, J=17.2 Hz, 2H, 2 ×=CHH), 5.82 (m, 2H, 2 ×=CH); δ_C (mixture of diastereomers) 14.3, 14.6 (2×CH$_2$CH_3), 20.5, 21.4, 26.8, 27.7, 28.7, 31.3, 33.7, 34.1, 34.3, 36.5 (10C, 10×CH_2), 26.6 [6C, 2×C(CH_3)$_3$], 35.8, 35.9 [2×C(CH_3)$_3$], 38.3, 38.4 (2×CHCH$_2$), 81.0 (2×CHOH), 114.3, 114.4 (2 ×=CH_2), 138.9, 139.0 (2 ×=CH); m/z 197 (M^+−15, 0.12%), 137 (27), 97 (10), 95 (48), 87 (100), 85 (13), 83 (19), 81 (55), 71 (40), 70 (14), 70 (55), 67 (23), 57 (72), 56 (14), 55 (52). HRMS: M^+, found 212.2189. $C_{14}H_{28}O$ requires 212.2140.

4.7.2.3. 1-Phenyl-2-propylhept-6-en-1-ol (20c). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3415 (OH), 3074, 3063, 3028, 1640 cm^{-1} (C=C); δ_H (mixture of diastereomers) 0.85 (m, 6H, 2×CH_3), 1.29 (m, 18H, 2×OH, 8×CH_2), 1.71 (m, 2H, 2×CHCHOH), 1.99 (m, 4H, 2×CH_2CH=CH_2), 4.65 (m, 2H, 2×CHOH), 4.94 (m, 4H, 2×CH_2=), 5.77 (m, 2H, 2×CH=), 7.30 (m, 10H, 2×ArH); δ_C (mixture of diastereomers) 14.4, 14.5 (2×CH_3), 20.0, 20.1, 26.2, 26.3, 28.1, 29.5, 30.9, 32.2 (8×CH_2), 34.0, 34.1 (2×CH$_2$CH=CH_2), 44.6, 44.7 (2×CHCHOH), 76.20, 76.22 (2×COH), 114.28, 114.33 (2×CH_2=), 126.4, 127.2, 128.2, 143.88, 143.94 (12×ArC), 138.9, 139.0 (2×CH=CH_2); m/z 233 (M^++1, 0.23%), 232 (M^+, 1.39%), 214 (M^+−18, 0.26%), 107 (100), 79 (21), 77 (10). HRMS: M^+, found 232.1835. $C_{16}H_{24}O$ requires 232.1827.

4.7.2.4. 1-(1-Propyl-5-hexenyl)cyclohexanol (20d). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3478 (OH), 3076, 1641 cm^{-1} (C=C); δ_H 0.90 (t, J=7.1 Hz, 3H, CH_3), 1.36 (m, 20H, 9×CH_2, CH and OH), 2.06 (m, 2H, CH_2CH=CH_2), 4.94 (d, J=10.1 Hz, 1H, CHH=CH), 5.00 (d, J=17.4 Hz, 1H, CHH=CH), 5.82 (m, 1H, CH=); δ_C 14.6 (CH_3), 21.9, 22.6, 25.9, 28.8, 29.7, 32.5, 34.4, 34.5 (10C, 10×CH_2), 48.8 (CH), 74.2 (COH), 114.3 (CH_2=), 139.0 (CH=); m/z 224 (M^+, 0.02%), 99 (100), 98 (13), 81 (35), 55 (20). HRMS: M^+, found 224.2127. $C_{15}H_{28}O$ requires 224.2140.

4.7.2.5. 2-Phenyl-3-propyloct-7-en-2-ol (20e). R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3479 (OH), 3061, 3026, 1640 cm^{-1} (C=C); δ_H (mixture of diastereomers) 0.84 (m, 6H, 2×CH$_2$CH_3), 1.36 (m with s at 1.52, 26H, 8×CH_2, 2×CH and 2×COHCH_3), 1.95 (m, 4H, 2×CH_2CH=CH_2), 4.92 (m, 4H, 2×CH_2=), 5.73 (m, 2H, 2×CH=CH_2), 7.23, 7.32, 7.42 (3m, 10H, 2×ArH); δ_C (mixture of diastereomers) 14.5, 14.6 (2×CH$_2$CH_3), 22.0, 22.3, 26.9, 27.0, 30.0, 30.1, 32.8, 32.9, 34.17, 34.25 (10C, 10×CH_2), 28.3, 28.5 (2×COHCH_3), 48.78, 48.82 (2×CH), 77.6 (2×COH), 114.2, 114.3 (2×CH_2=), 125.3, 126.4, 127.9, 148.4 (12C, 12×ArC), 138.87, 138.93 (2×CH_2=CH); m/z 228 (M^+−18, 0.9%), 131 (28), 121 (100), 105 (13), 91 (12). HRMS: M^+−[C_5H_9] first diastereomer, found 177.1259. $C_{12}H_{17}O$ requires 177.1279. M^+−[C_5H_9] second diastereomer, found 177.1248. $C_{12}H_{17}O$ requires 177.1279.

4.7.3. Preparation of compounds 22. To a stirred green suspension of lithium powder (40 mg, 5.8 mmol) and DTBB (13.3 mg, 0.05 mmol) in THF (3 mL) at −30°C was added a mixture of 6-chlorononon-1-ene (**18**; 0.080 g, 0.5 mmol) and the corresponding electrophile (0.55 mmol) in THF (1 mL) under an argon atmosphere. When the addition was finished (1 h), the mixture was stirred one more hour (the solution recovered the green colour) and then it was hydrolysed with 2 M HCl (5 mL) at the same temperature (−30°C), and stirred allowing the temperature to rise to room temperature. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and then was concentrated under vacuum (15 Torr). Compounds **22** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in Table 8; physical, spectroscopic and analytical data follows.

4.7.3.1. 3-(2-Propylcyclopentylmethyl)pentan-3-ol (22a). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3471 cm^{-1} (OH); δ_H 0.85 (def. t, J=6.8 Hz, 3H, CH$_2$CH$_2$CH_3), 0.87 (t, J=7.3 Hz, 3H, COHCH$_2$CH_3), 0.89 (t, J=7.3 Hz, 3H, COHCH$_2$CH_3), 1.35 (m, 17H, 2×CH, 7×CH_2 and OH), 1.78 (m, 1H, CHH), 1.96 (m, 1H, CHH);

δ_C 7.7, 8.1 (2×COHCH$_2$*C*H$_3$), 14.4 (CH$_2$CH$_2$*C*H$_3$), 21.7, 24.0, 30.9, 31.1, 31.6, 34.2, 37.0 (7×CH$_2$), 41.4, 43.4 (2×CH), 46.9 (CH$_2$), 75.1 (COH); *m/z* 194 (M^+-18, 0.14%), 183 (13), 109 (13), 87 (100), 69 (32), 67 (12), 57 (14), 55 (19). HRMS: M^+, found 212.2193. $C_{14}H_{28}O$ requires 212.2140.

4.7.3.2. 3,3-Dimethyl-1-(2-propylcyclopentyl)butan-2-ol (22b). R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3472 cm^{-1} (OH); δ_H (mixture of diastereomers) 0.91 (m, 24H, 8×CH$_3$), 1.51 (m, 30H, 12×CH$_2$, 4×CH and 2×OH), 3.24 (m, 2H, 2×C*H*OH); δ_C (mixture of diastereomers) 14.4, 14.5 (2×CH$_2$*C*H$_3$), 21.6, 21.7, 23.5, 24.2, 31.8, 32.2, 33.9, 36.9, 37.2, 37.7, 38.2 (12×CH$_2$), 25.7 [6C, 2×C(*C*H$_3$)$_3$], 34.8, 35.0 [2×*C*(CH$_3$)$_3$], 42.6, 43.9, 45.5, 46.3 (4×CH), 78.5, 79.7 (2×COH); *m/z* (first diastereomer) 197 (M^+-15, 0.13%), 194 (M^+-18, 0.48%), 155 (28), 137 (64), 111 (32), 110 (44), 109 (29), 95 (100), 87 (18), 83 (11), 82 (11), 81 (92), 70 (16), 69 (91), 67 (40), 57 (42), 56 (10), 55 (49); (second diastereomer) 197 (M^+-15, 0.18%), 194 (M^+-18, 0.55%), 155 (30), 137 (65), 111 (33), 110 (45), 109 (29), 96 (10), 95 (100), 87 (17), 83 (11), 82 (12), 81 (92), 70 (16), 69 (94), 67 (40), 57 (43), 56 (10), 55 (47). HRMS first diastereomer: $M^+-[CH_3]$, found 197.1903. $C_{13}H_{25}O$ requires 197.1905. HRMS second diastereomer: $M^+-[CH_3]$, found 197.1907. $C_{16}H_{23}O$ requires 197.1905.

4.7.3.3. 1-Phenyl-2-(2-propylcyclopentyl)ethanol (22c, first diastereomer). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3383 (OH), 3085, 3062, 3028 cm^{-1} (C=C); δ_H 0.88 (t, *J*=7.1 Hz, 3H, CH$_3$), 1.54 (m, 15H, 2×CH, 6×CH$_2$ and OH), 4.71 (dd, *J*=9.7 Hz, 3.5, 1H, C*H*OH), 7.30 (m, 5H, ArH); δ_C 14.4 (CH$_3$), 21.6, 23.6, 32.0, 32.1, 37.2 (5×CH$_2$), 42.5 (CH), 45.1 (CH$_2$), 46.1 (CH), 73.6 (COH), 125.7, 127.4, 128.4, 145.6 (6C, ArC); *m/z* 233 (M^++1, 0.04%), 232 (M^+, 0.20%), 108 (13), 107 (100), 79 (21), 77 (11). HRMS: M^+, found 232.1810. $C_{16}H_{24}O$ requires 232.1827.

4.7.3.4. 1-Phenyl-2-(2-propylcyclopentyl)ethanol (22c, second diastereomer). R_f 0.2 (hexane/ethyl acetate: 9/1); ν (film) 3371 (OH), 3084, 3062, 3028 cm^{-1} (C=C); δ_H 0.85 (t, *J*=7.1 Hz, 3H, CH$_3$), 1.49 (m, 15H, 2×CH, 6×CH$_2$ and OH), 4.68 (dd, *J*=7.7 Hz, 6.7, 1H, C*H*OH), 7.30 (m, 5H, ArH); δ_C 14.4 (CH$_3$), 21.5, 23.9, 31.8, 32.6, 37.2 (5×CH$_2$), 42.5 (CH), 44.5 (CH$_2$), 46.0 (CH), 74.4 (COH), 126.2, 127.6, 128.5, 144.6 (6C, ArC); *m/z* 233 (M^++1, 0.04%), 232 (M^+, 0.20%), 108 (10), 107 (100), 79 (23), 77 (11). HRMS: M^+, found 232.1834. $C_{16}H_{24}O$ requires 232.1827.

4.7.3.5. 1-(2-Propylcyclopentylmethyl)cyclohexanol (22d). R_f 0.3 (hexane/ethyl acetate: 9/1); ν (film) 3466 cm^{-1} (OH); δ_H 0.89 (t, *J*=7.1 Hz, 3H, CH$_3$), 1.52 (m, 25H, 11×CH$_2$, 2×CH and OH); δ_C 14.5 (CH$_3$), 21.7, 22.2, 22.3, 24.1, 25.8, 31.2, 34.6, 37.0, 37.6, 38.4 (11C, 11×CH$_2$), 41.0, 46.9 (2×CH), 71.9 (COH); *m/z* 206 (M^+-18, 1.5%), 115 (11), 111 (10), 110 (85), 109 (13), 99 (100), 98 (11), 95 (12), 82 (15), 81 (45), 79 (13), 69 (34), 67 (47), 55 (34). HRMS: M^+, found 224.2076. $C_{15}H_{28}O$ requires 224.2140.

4.7.3.6. 2-Phenyl-1-(2-propylcyclopentyl)propan-2-ol (22e). R_f 0.2 (hexane/ethyl acetate: 9/1); ν (film) 3452 (OH), 3086, 3059, 3026, 1602 cm^{-1} (C=C); δ_H (mixture of diastereomers) 1.29 (m with 2 s at 1.55 and 1.57, 40H, 4×CH$_3$, 12×CH$_2$ and 4×CH), 7.32 (3m, 10H, 2×ArH); δ_C (mixture of diastereomers) 14.39, 14.42 (2×CH$_2$*C*H$_3$), 21.5, 21.6, 23.9, 24.0, 30.99, 31.06 (6×CH$_2$), 30.3, 31.2 (2×COH*C*H$_3$), 33.8, 33.9, 36.5, 36.8 (4×CH$_2$), 41.76, 41.79 (2×*C*HCH$_2$COH), 46.6, 46.7 (2×*C*HCH$_2$CH$_2$CH$_3$), 49.3, 49.7 (2×*C*H$_2$COH), 74.8, 75.4 (2×COH), 124.8, 126.3, 126.4, 127.95, 127.98, 148.2, 148.7 (12C, ArC); *m/z* (first diastereomer) 246 (M^+, 0.23%), 121 (100), 118 (20); (second diastereomer) 231 (M^+-15, 0.38%), 121 (100), 118 (20). HRMS first diastereomer: $M^+-[CH_3]$, found 231.1735. $C_{16}H_{23}O$ requires 231.1749. HRMS second diastereomer: $M^+-[CH_3]$, found 231.1744. $C_{16}H_{23}O$ requires 231.1749.

4.7.3.7. 2-Methyl-1-(2-propylcyclopentyl)propan-2-ol (22f). R_f 0.2 (hexane/ethyl acetate: 9/1); ν (film) 3401 cm^{-1} (OH); δ_H 0.89 (def. t, *J*=7.1 Hz, 3H, CH$_2$C*H*$_3$), 1.54 [m with s at 1.23, 21H, COH(C*H*$_3$)$_2$, 6×CH$_2$, 2×CH and OH]; δ_C 14.4 (CH$_2$*C*H$_3$), 21.7, 24.1, 31.3, 34.4, 36.9, 49.1 (6×CH$_2$), 29.6, 30.2 [COH(*C*H$_3$)$_2$], 42.2, 46.9 (2×CH), 71.5 (COH); *m/z* 169 (M^+-15, 2.3%), 166 (M^+-18, 0.48%), 110 (17), 69 (17), 67 (21), 59 (100), 55 (14). HRMS: $M^+-[H_2O]$, found 166.1741. $C_{12}H_{22}$ requires 166.1722.

4.8. DTBB-catalysed lithiation of 6-chloro-6-ethyloct-1-ene (23)

4.8.1. Preparation of compound 23. *Preparation of 3-ethyloct-7-en-3-ol*. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (26 mg, 0.1 mmol) in THF (4 mL) at −78°C was added 5-bromopent-1-ene (0.125 mL, 1.0 mmol). The colour disappeared after the substrate addition, the reaction mixture was stirred until the green colour was recovered (45 min), and pentan-3-one (1.1 mmol) was then added. The resulting mixture was stirred for 15 min at the same temperature (−78°C), then it was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature for 10 min. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and was concentrated under vacuum (15 Torr). 0.13 g (82%) of the title compound were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures).

4.8.1.1. 3-Ethyloct-7-en-3-ol.[55] R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3404 (OH), 3076, 1641 cm^{-1} (C=C); δ_H 0.86 (t, *J*=7.3 Hz, 6H, 2×CH$_3$), 1.13 (s, 1H, OH), 1.46 (m, 8H, 4×CH$_2$), 2.06 (m, 2H, =CHC*H*$_2$), 4.96 (d, *J*=9.8 Hz, 1H, C*H*H=), 5.02 (d, *J*=17.1 Hz, 1H, CH*H*=), 5.82 (m, 1H, =CH); δ_C 7.7 (2×CH$_3$), 22.7, 31.0, 34.2, 37.6 (5×CH$_2$), 74.5 (COH), 114.5 (CH$_2$=), 138.7 (=CH); *m/z* 138 (M^+-18, 0.7%), 127 (20), 109 (13), 87 (83), 69 (22), 67 (16), 57 (100), 55 (50), 53 (11), 45 (68), 43 (43), 41 (60).

Preparation of 6-chloro-6-ethyloct-1-ene. 3-Ethyloct-7-en-3-ol (0.934 g, 6.0 mmol) and concentrated HCl (10 mL) were shaken vigorously in a separation funnel for 10 min. The product was extracted with pentane (3×15 mL). The organic layer was dried over anhydrous sodium sulphate and then was concentrated under vacuum (15 Torr) to give 1.05 g (>99%) of the title compound after purification by distillation at normal pressure.

4.8.1.2. 6-Chloro-6-ethyloct-1-ene (23). R_f 0.8 (hexane), ν (film) 3076, 1642 cm^{-1} (C=C); δ_H 0.95 (t, *J*=7.3 Hz, 6H, 2×CH$_3$), 1.51 (m, 2H, CH$_2$), 1.76 (m, 6H, 3×CH$_2$), 2.07 (m, 2H, =CHC*H*$_2$), 4.97 (d, *J*=9.8 Hz, 1H, C*H*H=), 5.03 (d, *J*=17.1 Hz, 1H, CH*H*=), 5.81 (m, 1H, =CH); δ_C 8.7

(2×CH_3), 23.5, 33.3, 33.8, 39.6 (5×CH_2), 79.4 (CCl), 114.8 (CH_2=), 138.4 (=CH); *m/z* 176 (M^++2, 0.3%), 174 (M^+, 0.8%), 109 (33), 97 (17), 96 (23), 84 (48), 83 (22), 81 (15), 69 (61), 68 (14), 67 (53), 56 (20), 55 (98), 54 (20), 53 (21), 43 (42), 42 (15), 41 (100).

4.8.2. Lithiation of compound 23. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (26.6 mg, 0.1 mmol) in THF (4 mL) at −30°C was added 6-chloro-6-ethyloct-1-ene (**23**; 0.175 g, 1.0 mmol) under an argon atmosphere. The colour disappeared after the substrate addition, the reaction mixture was stirred until the green colour was recovered (30 min) and pentan-3-one (0.118 mL, 1.1 mmol) was added. The resulting mixture was stirred for 15 min at the same temperature (−30°C), then it was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature for 10 min. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and then was concentrated under vacuum (15 Torr). 0.17 g (75%) of compound **27** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures).

Barbier type reaction. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (26.6 mg, 0.1 mmol) in THF (4 mL) at 0°C was added a solution of 6-chloro-6-ethyloct-1-ene (**23**; 0.175 mL, 1.0 mmol) and pentan-3-one (0.118 mL, 1.1 mmol) in THF (1.5 mL) over a 30 min period, the reaction was stirred for 15 additional minutes at the same temperature and then it was quenched and worked-up as above, yielding 0.17 g (75%) of compound **27**.

4.8.2.1. 3-[(2,2-Diethylcyclopentyl)methyl]pentan-3-ol (27). R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3463 cm^{-1} (OH); δ_H 0.83 (t, *J*=7.3 Hz, 6H, 2×CH_3), 0.87 (t, *J*=7.3 Hz, 6H, 2×CH_3), 1.06 (s, 1H, OH), 1.24 (m, 6H, 3×CH_2), 1.54 (m, 8H, 4×CH_2), 1.69 (d, *J*=7.9 Hz, 2H, CH_2COH), 1.98 (m, 1H, C*H*CH_2COH); δ_C 7.7, 8.0 (2×CH_3), 8.6, 8.7 (2×CH_3), 22.0, 25.1, 28.4, 30.8, 31.7, 32.3, 32.6, 38.5 (8C, 8×CH_2), 41.1 (CH), 46.9 (CH_2*C*CH_2), 75.2 (COH); *m/z* 208 (M^+−18, 1.0%), 109 (14), 95 (28), 87 (100), 83 (21), 81 (15), 69 (59), 67 (20), 57 (31), 55 (50), 45 (49), 43 (28), 41 (58). HRMS: M^+−[H_2O], found 208.2160. $C_{15}H_{28}$ requires 208.2191.

4.9. DTBB-catalysed lithiation of allyl 2-chlorophenyl ether (1-allyloxy-2-chlorobenzene) (28)

4.9.1. Preparation of compound 28.[42] NaH (0.186 g, 4.7 mmol, 60% in mineral oil) was washed with THF (3×7 mL) at 0°C and to the resulting solid was added a solution of 2-chlorophenol (0.423 mL, 4 mmol) in dry THF (1 mL). The mixture was stirred 2 h at room temperature and after cooling at 0°C allyl bromide (0.699 mL, 8 mmol) was added. The resulting solution was stirred overnight, washed with brine (20 mL) and the aqueous phase was extracted with diethyl ether (4×3 mL). The organic layer was washed with 10% NaOH (2×2 mL) and brine (2 mL) and was dried over anhydrous magnesium sulphate. The solvents were concentrated (15 Torr) and the yellow oil obtained was purified by column chromatography (silica gel, hexane/ethyl acetate) to give 0.60 g (90%) of compound **28**.

4.9.1.1. Allyl 2-chlorophenyl ether (1-allyloxy-2-chlorobenzene) (28).[56] R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3068, 1649 cm^{-1} (C=C); δ_H 4.61 (dd, *J*=5.2 Hz, 1.5, 2H, OCH_2), 5.31 (d, *J*=10.4 Hz, 1H, C*H*H=), 5.47 (d, *J*=1.8 Hz, 1H, CH*H*=), 6.07 (m, 1H, C*H*=CH_2), 6.90, 7.21, 7.36 (3m, 4H, ArH); δ_C 69.6 (OCH_2), 113.8, 121.5, 123.0, 127.6, 130.3, 154.1 (6C, ArC), 117.8 (=CH_2), 132.7 (*C*H=CH_2); *m/z* 170 (M^++2, 10.5%), 169 (M^++1, 3.5%), 168 (M^+, 32%), 133 (30), 128 (28), 99 (15), 75 (13), 73 (12), 64 (12), 63 (17), 41 (100).

4.9.2. Lithiation of compound 28. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (26.6 mg, 0.1 mmol) in THF (4 mL) at −78°C or −30°C was added allyl 2-chlorophenyl ether (**28**; 0.169 g, 1.0 mmol) under an argon atmosphere. The colour disappeared after the substrate addition, the reaction mixture was stirred until the green colour was recovered (30 min) and pentan-3-one (0.118 mL, 1.1 mmol) was added. The resulting mixture was stirred for 15 min at the same temperature (−78°C or −30°C), then it was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and then was concentrated under vacuum (15 Torr). Compound **31** was isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures) obtaining 0.123 g (56%) and 0.10 g (45%) for the reaction at −30 and −78°C, respectively.

4.9.2.1. 3-(2-Ethyl-2-hydroxybutyl)dihydrobenzo[*b*]-furan (31).[57] R_f 0.2 (hexane/ethyl acetate: 8/2); ν (film) 3453 (OH), 3080, 3073, 3060, 1598, 1478 cm^{-1} (C=C); δ_H 0.905 (t, *J*=7.3 Hz, 3H, CH_3), 0.913 (t, *J*=7.3 Hz, 3H, CH_3), 1.26 (s, 1H, OH), 1.55 (m, 4H, 2×C$H_2$$CH_3$), 1.72 (dd, *J*=14.3 Hz, 2.1, 1H, CHCH*H*), 2.04 (dd, *J*=14.7 Hz, 10.3, 1H, CHC*H*H), 3.63 (m, 1H, C*H*CH_2), 4.27 (def. t, *J*=8.9 Hz, 1H, CH*H*O), 4.77 (def. t, *J*=8.9 Hz, 1H, C*H*HO), 6.82, 7.17 (2m, 4H, ArH); δ_C 7.6, 8.2 (2×CH_3), 30.5, 32.0 (2×*C*$H_2$$CH_3$), 37.6 (*C*$HCH_2$), 43.5 (*C*$H_2$COH), 74.7 (COH), 78.6 ($OCH_2$), 159.7, 131.4, 128.0, 120.3, 115.3, 109.4 (6C, ArC); *m/z* 222 (M^++2, 0.3%), 221 (M^++1, 1.5%), 220 (M^+, 9.6%), 202 (M^+−18, 9.3%), 173 (53), 131 (12), 119 (100), 118 (18), 91 (84), 65 (18), 57 (32), 55 (15), 45 (28), 43 (17), 41 (20).

4.10. DTBB-catalysed lithiation of *N*,*N*-diallyl-2-chloroaniline 32

4.10.1. Preparation of compound 32. 2-Chloroaniline (0.537 mL, 5 mmol) was dissolved in dry THF (3 mL) under an argon atmosphere. The flask was introduced into a cooled bath (−30°C) and *n*-BuLi (3.13 mL of a 1.6 M solution in hexane, 5 mmol) was added. After 15 min stirring allyl bromide was added (0.524 mL, 6 mmol) and the solution was stirred 1 h at 0°C. The mixture was cooled to −30°C and *n*-BuLi was again added (3.13 mL of a 1.6 M solution in hexane, 5 mmol), the solution was stirred 15 min and allyl bromide was added (0.524 mL, 6 mmol). The reaction mixture was warmed to 0°C and stirred 1 h and it was hydrolysed with H_2O (15 mL). The product was extracted with diethyl ether (3×15 mL), the organic layer was dried over anhydrous magnesium sulphate and the solvents were concentrated under vacuum (15 Torr). The residue was

purified by column chromatography (silica gel, hexane/ethyl acetate) to obtain 0.88 g (85%) of pure compound **32**.

4.10.1.1. *N*,*N*-Diallyl-2-chloroaniline (32).[56] R_f 0.4 (hexane); ν (film) 3073, 3009, 1588, 1642, 1480 cm^{-1} (C=C); δ_H 3.71 (d, J=6.1 Hz, 4H, 2×NCH_2), 5.16 (dd, J=17.1 Hz, 10.4, 4H, 2×CH_2=), 5.81 (m, 2H, 2×C*H*=CH_2), 6.92, 7.02, 7.15, 7.34 (4m, 4H, ArH); δ_C 54.8 (2C, 2×NCH_2), 117.5 (2C, 2×CH_2=), 123.3, 123.5, 126.8, 129.6, 130.6, 147.6 (6C, ArC), 134.7 (2C, 2×*C*H=CH_2); *m*/*z* 209 (M^++2, 16.6%), 208 (M^++1, 10.5%), 207 (M^+, 50.3%), 206 (12), 182 (23), 180 (79), 178 (22), 173 (13), 172 (100), 166 (10), 164 (19), 144 (11), 140 (35), 139 (28), 138 (85), 131 (19), 130 (86), 113 (16), 111 (50), 77 (21), 75 (23), 51 (13).

4.10.2. Lithiation of compound 32. To a stirred green suspension of lithium powder (50 mg, 7.2 mmol) and DTBB (26.6 mg, 0.1 mmol) in THF (4 mL) at −78°C or −30°C was added *N*,*N*-diallyl-2-chloroaniline (**32**; 0.210 g, 1.0 mmol) under an argon atmosphere. The colour disappeared after the substrate addition, the reaction mixture was then stirred until the green colour was recovered (1 h) and pentan-3-one (0.118 mL, 1.1 mmol) or D_2O (0.050 mL, 2.5 mmol) were added. The resulting mixture was stirred for 1 h at the same temperature (−78 or −30°C), then it was hydrolysed with 2 M HCl (5 mL) and stirred to room temperature for 10 min. The reaction mixture was extracted with diethyl ether (3×15 mL), the organic phase was dried over anhydrous magnesium sulphate and the solvents were concentrated under vacuum (15 Torr). Compounds **33**, **34a**, **34b**, **35a**, **35b** were isolated after column chromatography (silica gel, hexane/ethyl acetate mixtures). Yields are given in the text; physical, spectroscopic and analytical data, as well as references for known compounds, follows.

4.10.2.1. *N*-Allyl-3-(2-ethyl-2-hydroxybutyl)indoline (33). R_f 0.2 (hexane/ethyl acetate: 8/2); ν (film) 3434 (OH), 3070, 3048, 3018, 1640 cm^{-1} (C=CH_2); δ_H 0.91 (t, J=7.3 Hz, 6H, 2×CH_3), 1.16 (s, 1H, OH), 1.57 (m, 4H, 2×C*H*$_2$$CH_3$), 2.08 (d, J=15.9 Hz, 2H, COHC*H*$_2$CH), 3.00 (t, J=9.2 Hz, 1H, NC*H*HCHCH_2), 3.34 (m, 1H, NCHHC*H*CH_2), 3.59 (m, 1H, NC*H*HCH=), 3.70 (t, J=5.8 Hz, 1H, NCH*H*CHCH_2), 3.81 (m, 1H, NCH*H*CH=), 5.24 (dd, J=17.1 Hz, 9.8, 2H, =CH_2), 5.57 (m, 1H, C*H*=CH_2), 6.51, 6.69, 7.07 (3m, 4H, ArH); δ_C 7.7, 8.2 (2xCH_3), 30.6, 32.0 (2x*C*$H_2$$CH_3$), 36.3 ($NCH_2$*C*H$CH_2$), 42.6, 52.0 (2x$CH_2$), 61.5 (COH), 117.8 ($CH_2$=), 107.4, 123.1, 127.4, 134.0, 151.6 (6C, Ar) 134.5 (*C*H=CH_2); *m*/*z* 261 (M^++2, 0.5%), 260 (M^++1, 5.8%), 259 (M^+, 25%), 170 (13), 159 (12), 158 (100), 157 (28), 156 (18), 130 (30), 118 (10), 117 (31). HRMS: M^+, found 259.1911. $C_{17}H_{25}NO$ requires 259.1936.

4.10.2.2. *N*-Allyl-3-methylindoline (34a).[58] R_f 0.5 (hexane/ethyl acetate: 9/1); ν (film) 3048, 3023, 1604, 1486, 1658 cm^{-1} (C=C); δ_H 1.30 (d, J=6.7 Hz, 3H, CH_3), 2.83 (t, J=8.5 Hz, 1H, NC*H*HCHCH_3), 3.27 (m, 1H, C*H*CH_3), 3.56 (t, J=8.5 Hz, 1H, NCH*H*CHCH_3), 3.63 (m, 1H, NC*H*HCH=), 3.78 (m, 1H, NCH*H*CH=), 5.24 (dd, J=17.1 Hz, 10.4, 2H, =CH_2), 5.93 (m, 1H, C*H*=CH_2), 6.53, 6.71, 7.09 (3m, 4H, ArH); δ_C 18.5 (CH_3), 35.1 (*C*HCH_3), 51.9 (N*C*H_2CH=), 61.2 (N*C*H_2CHCH_3), 107.3, 117.6, 123.1, 127.3, 135.2, 151.7 (6C, Ar), 117.2 (=CH_2), 134.2 (*C*H=CH_2); *m*/*z* 175 (M^++2, 0.8%), 174 (M^++1, 12.5%), 173 (M^+, 100), 172 (18), 159 (12), 158 (94), 156 (10), 146 (58), 144 (13), 143 (11), 132 (12), 131 (27), 130 (68), 118 (17), 117 (67), 115 (11), 103 (13), 91 (12), 77 (24).

4.10.2.3. *N*-Allyl-3-(deuteriomethyl)indoline (34b).[59] R_f 0.4 (hexane/ethyl acetate: 9/1); ν (film) 3073, 1595 cm^{-1} (C=C); δ_H 0.88 (m, 2H, CH_2D), 2.85 (t, J=8.5 Hz, 1H, NC*H*HCHCH_2D), 3.29 (m, 1H, C*H*CH_2D), 3.55 (t, J=8.5 Hz, 1H, NCH*H*CHCH_2D), 3.61 (m, 1H, NC*H*HCH=), 3.78 (m, 1H, NCH*H*CH=), 5.24 (dd, J=17.1 Hz, 9.8, 2H, =CH_2), 5.91 (m, 1H, C*H*=CH_2), 6.51, 6.69, 7.07 (3m, 4H, ArH); δ_C 18.0, 18.2, 18.5 (CH_2D), 35.0, 35.1 (*C*HCH_2D), 52.0 (*C*H_2CH=CH_2), 61.2 (NCH_2-CHCH_2D), 107.4, 117.8, 123.1, 127.3, 135.2, 151.7 (ArC), 117.22 (CH=*C*H_2), 134.2 (*C*H=CH_2); *m*/*z* 176 (M^++2, 0.8%), 175 (M^++1, 12.1%), 174 (M^+, 96.6%), 173 (36), 159 (15), 158 (100), 147 (54), 146 (13), 143 (12), 133 (12), 132 (21), 131 (39), 130 (47), 118 (25), 117 (68), 116 (11), 103 (10), 91 (12), 90 (10), 89 (10), 78 (13), 77 (20).

4.10.2.4. *N*,*N*-Diallyl-2-(1-ethyl-1-hydroxypropyl)aniline (35a). R_f 0.3 (hexane/ethyl acetate: 8/2); ν (film) 3429 (OH), 3076, 1640 cm^{-1} (C=C); δ_H 0.79 (t, J=7.3 Hz, 6H, 2×CH_3), 1.78 (m, 4H, 2×C*H*$_2$$CH_3$), 3.55 (m, 4H, 2×$NCH_2$), 5.15 (dd, J=17.1 Hz, 11.0, 4H, 2×CH=C*H*$_2$), 5.92 (m, 2H, 2×C*H*=CH_2), 7.18 (m, 4H, ArH), 9.89 (s, 1H, OH); δ_C 8.5 (2×CH_3), 37.1 (2×*C*$H_2$$CH_3$), 59.0 (2×$NCH_2$), 80.6 (COH), 118.9 (2×CH=*C*H_2), 125.0, 126.1, 126.8, 128.1, 141.0, 149.7 (6C, Ar), 134.0 (2×*C*H=CH_2); *m*/*z* 260 (M^++1, 2.4%), 259 (M^+, 9.0%), 231 (13), 230 (79), 218 (16), 212 (13), 201 (16), 200 (100), 190 (12), 175 (11), 174 (79), 172 (13), 171 (11), 170 (16), 160 (48), 158 (18), 156 (11), 146 (14), 144 (30), 143 (10), 134 (14), 133 (51), 132 (42), 131 (13), 130 (37), 120 (10), 118 (14), 117 (23), 115 (16), 91 (14), 77 (20), 57 (21). HRMS: M^+, found 259.1920. $C_{17}H_{25}NO$ requires 259.1936.

4.10.2.5. *N*,*N*-Diallyl-2-deuterioaniline (35b). R_f 0.3 (hexane); ν (film) 3070, 3048, 3023, 1644, 1606 cm^{-1} (C=C); δ_H 3.92 (d, J=3.05 Hz, 4H, 2×NCH_2), 5.18 (dd, J=17.1 Hz, 7.3, 4H, 2×CH_2=), 5.86 (m, 2H, 2×C*H*=CH_2), 6.69, 7.20 (2m, 4H, ArH); δ_C 52.7 (2C, 2×NCH_2), 112.3, 116.2, 128.9, 129.0, 148.7 (6C, ArC), 115.9 (2×*C*H_2=CH), 134.0 (2×*C*H=CH_2); *m*/*z* 176 (M^++2, 0.7%), 175 (M^++1, 9.8%), 174 (M^+, 79%), 173 (30), 148 (12), 147 (100), 146 (26), 145 (27), 133 (10), 132 (15), 131 (47), 130 (17), 119 (14), 118 (21), 106 (31), 105 (67), 104 (18), 78 (63), 77 (18), 52 (14), 51 (17). HRMS: M^+, found 174.1257. $C_{12}H_{14}DN$ requires 174.1266.

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