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1,3-Chirality Transfer by Fragmentation of Allylsulfinic Acids: A Diastereoselective Approach to Vinyl Bromides Related to *trans*-Hydrindane or *trans*-Decalin

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Diastereoselective approaches to vinyl bromides from bromoallylic alcohols by fragmentation of the respective allylsulfinic acids have been investigated. Bromoallylic alcohols **1a** and **6** were transformed into the respective 1,3-benzothiazol-2-yl sulfides **2a** and **7** by the Mitsunobu inversion reaction under modified conditions. The sulfides were then oxidized into sulfones **11a** and **12a**, respectively. Reduction of **11a** and **12a** with sodium borohydride gave the respective allylsulfinic acid salts **13a** and **15** which, without isolation, were treated with aqeous tartaric acid. The salt **13a** gave exclusively 5α-cholestane derivative **14a** whereas **15** provided a mixture of the 5α and 5β derivatives **16** and **17** (after deprotection), the former prevailing. In an alternative approach, benzothiazolyl sulfides **2a** and **7** were treated sequentially with BH_3·THF and $LiAlH_4$ to give thiols **18a** and **19a**, respectively. Oxidation of thiols **18a** and **19a** with oxaziridine **21** gave the respective sulfinic acids which, on gentle heating, afforded bromoolefins **14a** and **22a**, respectively, as the only products. Analogous reaction sequences starting from allylic alcohols devoid of the bromine substituent **1b** and **8** have also been studied.

Introduction

Vinyl halides are important intermediates in convergent syntheses owning to their applications in various cross-coupling reactions.[1] In conjunction with our work in the field of vitamin D synthesis,[2,3] we were interested in developing a synthetic approach to vinyl bromides related to *trans*-hydrindane[4] (*i*, *n* = 1, Figure 1). Bromoallylic alcohols *ii* (*n* = 2) appear to be plausible intermediates in the synthesis as these compounds are easily accessible from common α,β-unsaturated ketones *iii* (*n* = 1). It was thought that the hydroxy group in *ii* (*n* = 1) could be substituted by the 1,3-benzothiazole-2-thio group in an Mitsunobu inversion reaction[5] to provide *iv* (*n* = 1). Oxidation of sulfides *iv* (*n* = 1) would then afford sulfones *v* (*n* = 1) which could be transformed into the corresponding sulfinic acid salts by reduction with sodium borohydride under mild conditions.[6] Free allylsulfinic acids *vi* (*n* = 1) could be generated from the salts by acidification.[7] Alternatively, removal of the benzothiazolyl group in *iv* (*n* = 1) would afford the respective thiols *vii* (*n* = 1) which could be oxidized directly to the allylsulfinic acids *vi* (*n* = 1). This latter species readily undergoes fragmentation with double bond transposition and expulsion of sulfur dioxide,[7–9] as indicated in Figure 1. Corey and Engler[10] have pioneered the application of allylsulfinic acid fragmentation in diastereospecific synthesis. However, this method of "1,3-chirality transfer" has received little attention thus far[11] even though it is of interest in its own right. In this paper we describe the synthesis of the vitamin D building block **22a** (see Scheme 7) from dione

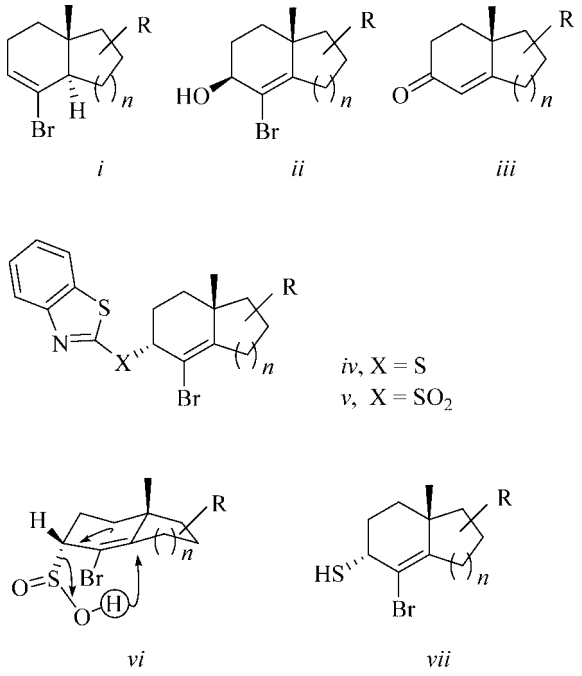

Figure 1. Structures involved in the general synthetic plan.

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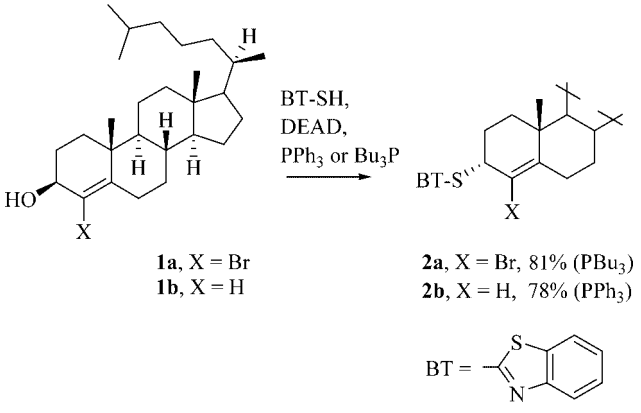
3 via bromoallylic alcohol **6** (see Scheme 2) and our model studies on the synthesis and fragmentation of allylsulfinic acids related to cholestane [the decalin system, transformation of *iii* (n = 2) into *i* (n = 2)].

Results and Discussion

Synthesis of Benzothiazolyl Sulfones 11a, 11b, 12a and 12b

Cholest-4-en-3-one was transformed into its 4-bromo derivative essentially according to the previously reported procedure[12,13] (for some modifications, see the Exptl. Sect.). Reduction of the bromo enone with sodium borohydride in the presence of cerium chloride (the Luche reagent[14]) provided allylic alcohol (**1a**, Scheme 1) in 91% yield. Treatment of **1a** with 1,3-benzothiazole-2-thiol, diethyl azodicarboxylate (DEAD) or diisopropyl azodicarboxylate (DIAD) and triphenylphosphane under the usual Mitsunobu inversion conditions[5,15] gave the substitution product in low yields. Replacement of triphenylphosphane with the more reactive tributylphosphane allowed benzothiazolyl sulfide **2a** to be obtained in 73% yield. Cholest-4-en-3β-ol **1b** was readily transformed into sulfide **2b** using DEAD and triphenylphosphane (78% yield).

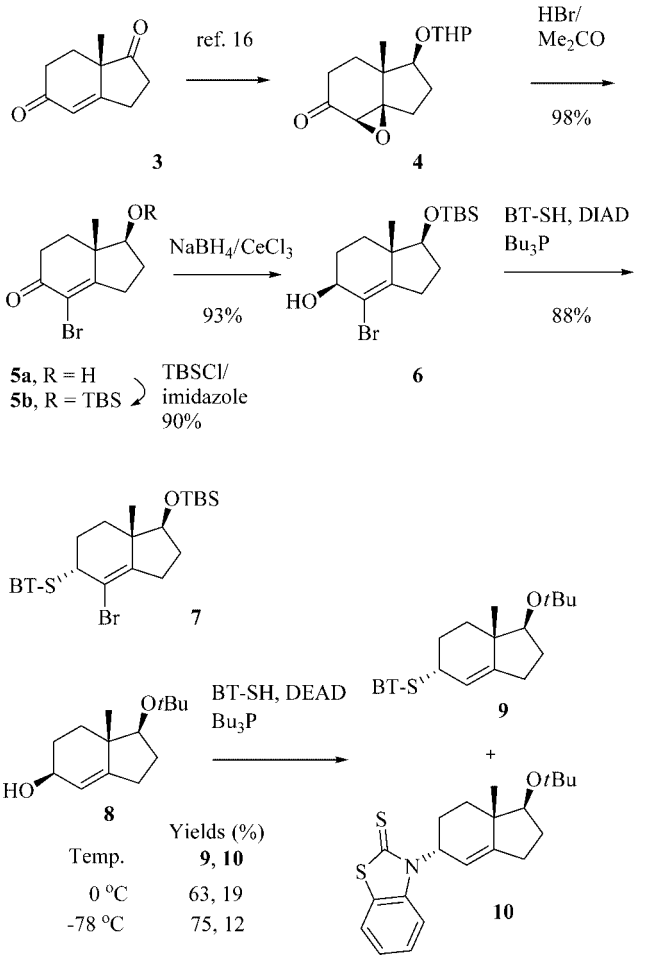


1a, X = Br
1b, X = H

2a, X = Br, 81% (PBu_3)
2b, X = H, 78% (PPh_3)

Scheme 1.

Epoxide **4** (Scheme 2), readily available[16] from the Hajos dione[17] **3**, was treated with 40% aqueous hydrobromic acid in acetone to give **5a**. The hydroxy group in **5a** was protected as the *tert*-butyldimethylsilyl ether and the derivative **5b** was subjected to reduction with the Luche reagent to give alcohol **6** in 82% yield from **4**. Alcohol **6**, treated with 1,3-benzothiazole-2-thiol, DEAD and tributylphosphane at 0 °C, afforded sulfide **7** as the only isolable product in 88% yield. Interestingly, alcohol **8**, lacking the bromine substituent, under similar conditions gave the *S*- and *N*-substituted products **9** and **10** in 63 and 19% yields, respectively. Lowering the reaction temperature to –78 °C affected the product ratio, giving **9** and **10** in 75 and 12% yields, respectively (Table 1).

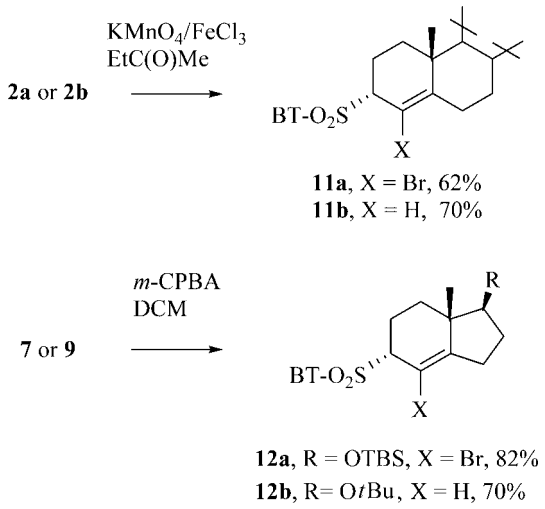


Scheme 2.

Table 1. Sulfur versus nitrogen substitution in the Mitsunobu inversion reaction of **8** under analogous conditions to the reaction of **1a** and **6**.

Phosphane	Diazo compd.	T [°C]	**8**/THF [mmol/L]	Product	% Yield
Ph_3P	DEAD	0	185.8	**9**	41
				10	13
Ph_3P	DIAD	0	185.8	**9**	60
				10	18
Bu_3P	DEAD	0	185.8	**9**	63
				10	19
Bu_3P	DIAD	–78	35.7	**9**	71
				10	14
Bu_3P	DEAD	–78	35.7	**9**	75
				10	12

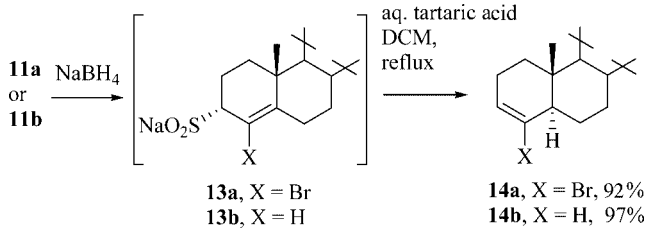
Sulfides **2a** and **2b** were oxidized with potassium permanganate in the presence of iron(III) chloride[18] in ethyl methyl ketone to give sulfones **11a** and **11b** (Scheme 3), respectively. Sulfides related to hydrindane, **7** and **9**, were conveniently oxidized to sulfones **12a** and **12b**, respectively, using *m*-CPBA in DCM. The yields are summarized in Scheme 3. All the sulfones were crystalline and stable.



Scheme 3.

Reduction of Benzothiazolyl Sulfones and Fragmentation of Allylsulfinic Acids

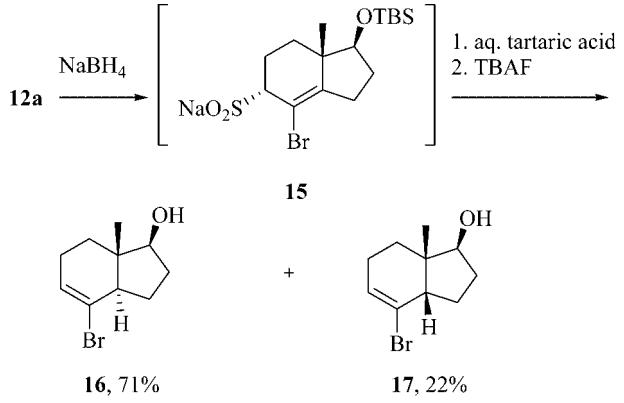
With these sulfones in hand the stage was set to generate sulfinic acids. Treatment of **11a** with 2 mol-equiv. of sodium borohydride in ethanol/THF at room temperature resulted in cleavage of the benzothiazole moiety and the production of a polar product to which the structure of sulfinic acid salt **13a** (Scheme 4) was assigned. The salt could not be isolated from the mixture containing the borohydride excess, benzothiazole and some side-products. Acidification of the mixture with dilute hydrochloric or sulfuric acid was accompanied by vigorous gas evolution and led to a mixture of several products.



Scheme 4.

Eventually a procedure for acidification was developed that led exclusively to **14a**. After the reduction step the crude mixture was evaporated and the semi-solid residue suspended in DCM. To this suspension at reflux, 0.9 M aqueous tartaric acid was added dropwise. After gas evolution had ceased, **14a** was isolated in 90% yield. In an analogous sequence of reactions **11b** was converted into **14b** in 97% yield.

The benzothiazolyl sulfone **12a** when treated first with sodium borohydride and then with aqueous tartaric acid in DCM afforded a *trans*-hydrindane derivative contaminated with its *cis* isomer. The isomers could not be separated by column chromatography, but the respective alcohols **16** and **17** (Scheme 5), prepared by treatment of the crude reaction mixture with TBAF in THF, were readily obtained in a pure form and fully characterized. Yields of these products and the isomer ratios varied somewhat. In a typical experiment on a 0.5 mmol scale, a mixture of **16** and **17** was obtained in 80% yield and with an isomer ratio of around 4:1.



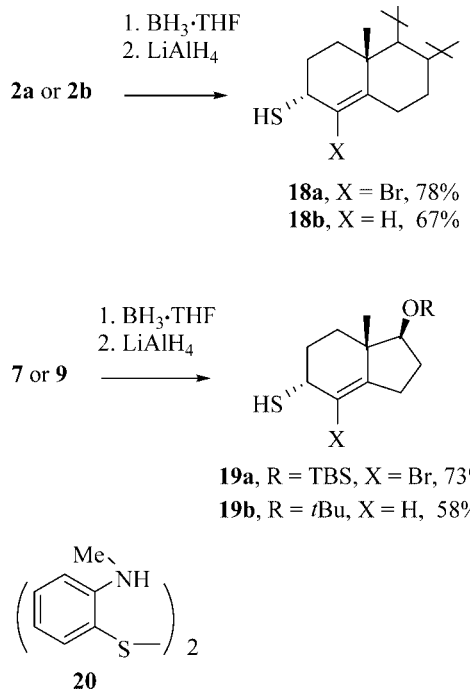
Scheme 5.

In an attempt to apply this method to the sulfone devoid of the bromine substituent (**12b**) a mixture of *trans* and *cis* isomers, as well as some dienes, was obtained, as determined by TLC and ^{1}H NMR analysis. This mixture could not be separated by column chromatography.

Although high selectivity was achieved in the allylsulfinic acid fragmentation step in the cholestane series, the method proved less favourable with the hydrindane derivatives. The generation of sulfinic acids from their salts under protic conditions is the likely critical step. It was thought that the benzothiazole moiety could be removed from the benzothiazolyl sulfides and then the allylic thiols would be directly oxidized to the respective sulfinic acids.

Synthesis of Allylsulfinic Acids by Oxidation of Allylic Thiols

Reported methods for the cleavage of non-activated 1,3-benzothiazol-2-yl alkyl sulfides involve quaternization of the heterocyclic nitrogen atom followed by treatment of the benzothiazolium salt with hydrazine[19] or the use of an excess of butyllithium.[20] In the search for a more suitable method for removing the "protecting" benzothiazolyl group, it was noted that treatment of bromo sulfide **2a** with 2 mol-equiv. of BH_3 in THF at –15 °C resulted in consumption of the starting material and the formation of a product that could be detected on TLC plates. This product (presumably an adduct), on quenching of the reaction with water, yielded the required thiol **18a** (Scheme 6) along with unchanged **2a**. The proportions of **18a** and **2a** appeared to depend upon the origin of the reagent. However, a substantial amount of **2a** was recovered even when freshly prepared BH_3·THF was used.



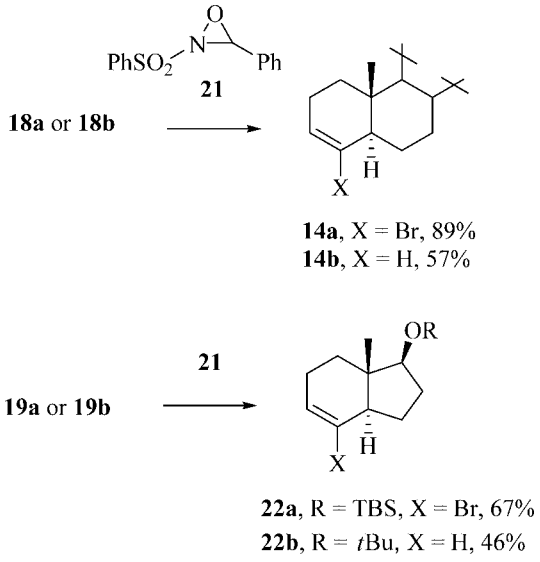
Scheme 6.

After some experimentation it was found that sulfide **2a** when treated first with BH_3·THF (at –15 °C) and then, after the staring material had been consumed, with lithium aluminium hydride affords thiol **18a** in 78% yield after chromatography. Careful rechromatography of the more polar fractions gave another product: *N*-methyl-2-(2-methylaminophenyldisulfanyl)aniline[21] (**20**). Apparently, the primary benzothiazolyl moiety reduction product, 2-(methylamino)benzenethiol, was oxidatively dimerized during the isolation procedure. Note, benzothiazolyl sulfide **2a** was recovered unchanged when it was treated with lithium aluminium hydride alone at –15 °C.

Under similar conditions using BH_3·THF and then $LiAlH_4$, three other benzothiazolyl sulfides **2b**, **7** and **9** were readily transformed into their respective thiols **18b**, **19a** and **19b**. The yields are summarized in Scheme 6.

Oxidation of thiol **18a** with 2 mol-equiv. of *m*-CPBA[10,22] at low temperatures (–90 or –78 °C) and then gentle warming of the reaction mixture to fragment the sulfinic acid led to a complex mixture of products. Analysis of these mixtures showed the presence of only small amounts of olefin **14a**. Similar results were obtained with the thiol devoid of the bromine substituent (**18b**). A milder oxidizing reagent appeared necessary.

We next turned our attention to Davis' oxaziridines,[23] which have previously been used for the oxidation of thiols to sulfinic acids.[24] Readily available *rac*-*trans*-3-phenyl-2-(phenylsulfonyl)oxaziridine[25] (**21**) (Scheme 7) was chosen. The best results were obtained when a solution of thiol **18a** in DCM was added to a solution of 2 mol-equiv. of **21** in DCM at 0 °C and the mixture then warmed to room temperature. The solvent was evaporated under reduced pressure in a warm water bath. The product was purified by chromatography to give vinyl bromide **14a** in 89% yield. Under similar conditions **18b** was transformed into **14b** in 57% yield. Gratifyingly, this method could also be successfully applied to bromo thiol **19a** to give the *trans*-hydrindane derivative **22a** in 67% yield. Thiol **19b**, devoid of the bromine substituent, was transformed into its respective counterpart **22b** in 46% yield.



Scheme 7.

To gain some insight into the generation of sulfinic acids via sulfinic acid salts and the subsequent fragmentation process, the oxidation of lithium thiolates[26] was briefly scrutinized. Thiol **18a** in THF at –78 °C was treated with 1 mol-equiv. of butyllithium in hexanes followed by 2 mol-equiv. of oxaziridine **21**. The cloudy solution was warmed to room temperature and then evaporated. The residue (amorphous solid) was triturated with hexanes in an attempt to wash out the sulfonylimine derivative and related byproducts. However, the lithium sulfinate salt (lithium counterpart of **13a**) could not be obtained in a pure form. The crude oxidation product was suspended in DCM, the suspension heated to reflux temperature and then aqueous tartaric acid was added. After the usual isolation, bromocholestene **14a** was obtained in 26% yield from **3a**. In the hydrindane series, thiol **19a** afforded the derivative **22a** in 46–58% yield. Note that the products obtained via lithium thiolates were of high purity.

To summarize, synthetic approaches to vinyl bromides **14a** and **22a** from bromoallylic alcohols **1a** and **6**, respectively, through sulfinic acid fragmentation have been developed. As part of this strategy, a new method for the synthesis of thiols from alcohols via benzothiazolyl sulfides has been developed.

Experimental Section

Melting points were determined on a hot-stage apparatus and are uncorrected. Optical rotations were measured in $CHCl_3$ on a Perkin-Elmer model 141 polarimeter using a 1 mL capacity cell (10 cm

path length). NMR spectra were recorded in $CDCl_3$: ^1H at 200 MHz and ^{13}C at 50 MHz with a Varian Gemini spectrometer or ^1H at 400 MHz and ^{13}C at 100 MHz with a Varian Mercury spectrometer or ^1H at 500 MHz and ^{13}C at 125 MHz with a Bruker AMX instrument. Chemical shifts are quoted on the δ scale with the solvent signal as the internal standard ($CHCl_3$: ^1H NMR δ = 7.26 ppm; $CDCl_3$: ^{13}C NMR δ = 77.00 ppm). The signals in the ^{13}C NMR spectra were assigned using the DEPT technique. MS (electron impact, 70 eV) were recorded with an AMD 604 spectrometer (AMD Intectra GmbH). GC analyses were performed using a Shimadzu GC-14A chromatograph equipped with a 0.32 mm × 30 m, Q5-30W-0.5F 0.5 μm 007–5 phase capillary column; injection temperature 150 °C, programmed temperature 10 °C/min. Column chromatography was performed on Merck silica gel 60, 230–400 mesh. TLC was performed on aluminium sheets, Merck 60F 254. Anhydrous solvents were obtained by distillation from benzophenone ketyl (THF) or calcium hydride (CH_2Cl_2). Commercially available hexane, as a mixture of isomers (Aldrich), was used. Air-sensitive reactions were performed in oven- or flame-dried glassware under argon. Organic extracts were dried with anhydrous Na_2SO_4 and solvents were evaporated in a rotary evaporator. Microanalyses were performed at our analytical laboratory.

4β,5-Epoxy-5β-cholest-3-one and 4α,5-Epoxy-5α-cholest-3-one: Perhydrol (30%, 12 mL) and aqueous NaOH (10%, 4 mL), precooled in an ice–water bath, were added to a solution of cholest-4-en-3-one (2.10 g, 5.46 mmol) in methanol (180 mL) stirred at 0 °C. The mixture was set aside at 0 °C for 48 h and then diluted with water (100 mL) and extracted with DCM (3 × 80 mL). The organic extract was dried and the solvent was evaporated. The residue was purified by chromatography on silica gel (40 g, 1.5% EtOAc/hexanes) to give consecutively the 4β,5β-epoxide (1.21 g, 55%) and the 4α,5α-epoxide (0.09 g, 4%). 4β,5β-Epoxide: M.p. 117–119 °C (acetone). ^1H NMR (200 MHz): δ = 0.68 (s, 3 H, 18-H), 0.861 and 0.865 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.90 (d, J = 6.8 Hz, 3 H, 21-H), 1.15 (s, 3 H, 19-H) overlapping 0.89–1.64 (m, 22 H), 1.66–2.40 (m, 6 H), 2.98 (s, 1 H, 4-H) ppm, in agreement with data reported elsewhere.[12,13] 4α,5α-Epoxide (0.09 g, 4%): M.p. 119–121 °C (acetone). ^1H NMR (200 MHz): δ = 0.70 (s, 3 H, 18 H), 0.86 and 0.87 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.91 (d, J = 6.4 Hz 3 H, 21-H), 1.05 (s, 3 H, 19-H) overlapping 1.00–2.49 (m, 28 H), 3.03 (s, 1 H, 4-H) ppm. $C_{27}H_{44}O_2$ (400.64): calcd. C 80.92, H 11.09; found C 80.90, H 11.11.

4-Bromocholest-4-en-3-one: Aqueous HBr (40%, 1.2 mL) was added to a solution of 4β,5-epoxy-5β-cholest-3-one (1.21 g, 3.02 mmol) in acetone (37 mL). The mixture was stirred for 2 h and then it was diluted with water (80 mL) and extracted with hexanes (3 × 50 mL). The organic extract was dried and evaporated to give 4-bromocholest-4-en-3-one (1.34 g, 96%). M.p. 115–116 °C (acetone). ^1H NMR (200 MHz): δ = 0.71 (s, 3 H, 18-H), 0.860 and 0.862 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.90 (d, J = 6.6 Hz, 3 H, 21-H), 1.23 (s, 3 H, 19-H) overlapping 0.94–2.10 (m, 24 H), 2.25 (dt, J = 14.8, 5.2 Hz, 1 H), 2.42–2.71 (m, 2 H), 3.2–3.4 (m, 1 H) ppm, in agreement with data reported elsewhere.[13]

Typically, a crude mixture of 4β,5β- and 4α,5α-epoxides obtained as described above was used for this reaction. Chromatography of the product gave 4-bromocholest-4-en-3-one and unchanged 4α,5α-epoxide.

4-Bromocholest-4-en-3β-ol (1a): $CeCl_3 \cdot 7H_2O$ (1.01 g, 2.71 mmol) followed (after the salt has dissolved) by $NaBH_4$ (0.12 g, 3.17 mmol) were added to a solution of 4-bromocholest-4-en-3-one (1.31 g, 2.83 mmol) in THF (22 mL) and methanol (7 mL) stirred at 0 °C. The mixture was left at 0 °C for 2 h and then acetone (3 mL) was added followed (after another 2 h) by water (100 mL). The product was extracted with DCM (3 × 50 mL). The organic extract was dried and the solvents evaporated. The residue was purified by chromatography on silica gel (40 g, 2% EtOAc/hexanes) to give **1a** (1.20 g, 91%). M.p. 122–123 °C (acetone). $[\alpha]_D^{23}$ = +62.7 (c = 1.04). ^1H NMR (200 MHz): δ = 0.68 (s, 3 H, 18-H), 0.858 and 0.861 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.89 (d, J = 7.2 Hz, 3 H, 21-H), 1.09 (s, 3 H, 19-H) overlapping 0.72–2.17 (m, 27 H), 2.38–2.48 (br. s, 1 H, OH), 2.80–2.94 (m, 1 H), 4.15–4.22 (m, 1 H, 3-H) ppm. $C_{27}H_{45}BrO$ (465.56): calcd. C 69.64, H 9.76, Br 17.16; found C 69.41, H 9.74, Br 17.19.

2-(4-Bromocholest-4-en-3α-ylthio)-1,3-benzothiazole (2a): DEAD (0.48 g, 0.43 mL, 2.76 mmol) in THF (7 mL) was added dropwise, at 0 °C, to a stirred solution of **1a** (0.85 g, 1.83 mmol), 1,3-benzothiazole-2-thiol (0.37 g, 2.20 mmol) and tributylphosphane (0.56 g, 0.68 mL, 2.77 mmol) in THF (10 mL). The mixture was stirred at 0 °C for 1 h and then it was warmed to room temp. After 2 h the solvent was evaporated. The residue was purified by chromatography on silica gel (40 g, 1% EtOAc/hexanes) to give **2a** (0.91 g, 81%). M.p. 131–133 °C (acetone). $[\alpha]_D^{23}$ = +14.6 (c = 1.16). ^1H NMR (200 MHz): δ = 0.68 (s, 3 H, 18-H), 0.865 and 0.870 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.90 (d, J = 6.2 Hz, 3 H, 21-H), 1.11 (s, 3 H, 19-H) overlapping 0.71–2.40 (m, 27 H), 2.88–3.02 (m, 1 H), 4.90–4.98 (br., 1 H, 3-H), 7.20–7.46 (m, 2 H, aromatic-H), 7.70–7.91 (m, 2 H, aromatic-H) ppm. $C_{34}H_{48}BrNS_2$ (614.78): calcd. C 66.41, H 7.88, Br 13.00, N 2.28, S 10.43; found C 66.29, H 7.96, Br 13.03, N 2.18, S 10.51.

2-(Cholest-4-en-3α-ylthio)-1,3-benzothiazole (2b): DEAD (0.58 g, 0.52 mL, 3.33 mmol) in THF (8 mL) was added dropwise, at 0 °C, to a stirred solution of alcohol **1b** (0.85 g, 2.20 mmol), 1,3-benzothiazole-2-thiol (0.44 g, 2.63 mmol) and triphenylphosphane (0.87 g, 3.32 mmol) in THF (12 mL). The mixture was stirred at 0 °C for 1 h and then it was warmed to room temp. After 2 h the solvent was evaporated and the residue was purified by chromatography on silica gel (30 g, 1% EtOAc/hexanes) to give **2b** (0.92 g, 78%). M.p. 170–171 °C (DCM). $[\alpha]_D^{23}$ = +53.6 (c = 0.98). ^1H NMR (200 MHz): δ = 0.69 (s, 3 H, 18-H), 0.87 (d, J = 6.7 Hz, 6 H, 26-H, 27-H), 0.90 (d, J = 7.4 Hz, 3 H, 21-H), 1.04 (s, 3 H, 19-H) overlapping 1.06–2.40 (m, 28 H), 4.60–4.70 (m, 1 H, 3-H), 5.50 (dd, J = 5.1, 1.3 Hz, 1 H, 4-H), 7.26–7.62 (m, 2 H, aromatic-H), 7.72–7.79 (m, 1 H, aromatic-H), 7.83–7.91 (m, 1 H, aromatic-H) ppm. $C_{34}H_{49}NS_2$ (535.89): calcd. C 76.20, H 9.22, N 2.61, S 11.98; found C 76.17, H 9.29, N 2.64, S 11.86.

(1*S*,7a*S*)-4-Bromo-1-hydroxy-7a-methyl-1,2,3,6,7,7a-hexahydro-5*H*-inden-5-one (5a): Aqueous HBr (40%, 2.00 mL) was added to a solution of **4**[16] (1.37 g, 5.14 mmol) in acetone (65 mL). The mixture was stirred for 24 h and then diluted with water (150 mL) and extracted with DCM (3 × 80 mL). The organic extract was dried with $MgSO_4$ and the solvent was evaporated. The residue was purified by chromatography on silica gel (35 g, 20% and then 50% EtOAc/hexanes) to give **5a** (1.24 g, 98%). M.p. 112–113 °C (acetone/pentane). $[\alpha]_D^{23}$ = +49.7 (c = 1.15). ^1H NMR (500 MHz): δ = 1.20 (d, J = 0.7 Hz, 3 H, CH_3), 1.80–1.93 (m, 3 H), 2.09–2.14 (m, 1 H), 2.16–2.23 (m, 1 H), 2.47–2.56 (m, 1 H), 2.63–2.80 (m, 3 H) 3.90–3.96 (m, 1 H, 1-H) ppm. ^{13}C NMR (50 MHz): δ = 15.1 (CH_3), 29.3, 29.8, 33.6, 34.1 (C-2, C-3, C-6, C-7), 48.9 (C-7a), 80.7 (C-1), 118.9 (C-4), 172.9 (C-3a), 190.4 (C-5) ppm. $C_{10}H_{13}BrO_2$ (245.12): calcd. C 49.00, H 5.35, Br 32.60; found C 48.97, H 5.50, Br 32.45.

(1*S*,7a*S*)-4-Bromo-1-(*tert*-butyldimethylsilyloxy)-7a-methyl-1,2,3,6,7,7a-hexahydro-5*H*-inden-5-one (5b): Imidazole (0.41 g, 6.02 mmol) and *tert*-butyldimethylsilyl chloride (0.91 g 6.04 mmol)

were added to a solution **5a** (1.23 g, 5.02 mmol) in DCM (35 mL). The mixture was set aside for 48 h and then it was poured into water (80 mL) and extracted with DCM (3 × 50 mL). The organic extract was dried and the solvents evaporated. The residue was purified by chromatography on silica gel (30 g, 10% EtOAc/hexanes) to give **5b** (1.63 g, 90%). M.p. 64–65 °C (ethanol/water). $[\alpha]_D^{23}$ = +36.6 (*c* = 1.07). ^{1}H NMR (200 MHz): δ = 0.05 and 0.06 (2s, 6 H, $Si(CH_3)_2$), 0.90 (s, 9 H, $C(CH_3)_3$), 1.15 (d, *J* = 0.4 Hz, 3 H, CH_3), 1.70–2.11 (m, 4 H), 2.35–2.86 (m, 4 H), 3.82 (dd, *J* = 10.6, 7.2 Hz, 1 H, 1-H) ppm. ^{13}C NMR (50 MHz): δ = –4.9, –4.5 ($Si(CH_3)_2$), 15.3 (CH_3), 18.0 ($C(CH_3)_3$), 25.7 ($C(CH_3)_3$), 29.7, 29.9, 33.8, 34.2 (C-2, C-3, C-6, C-7), 49.4 (C-7a), 80.8 (C-1), 118.7 (C-4), 173.1 (C-3a), 190.5 (C-5) ppm. $C_{16}H_{27}BrO_2Si$ (359.38): calcd. C 53.47, H 7.57, Br 22.23; found C 53.43, H 7.48, Br 22.32.

(1*S*,5*S*,7a*S*)-4-Bromo-1-(*tert*-butyldimethylsilyloxy)-7a-methyl-1,2,3,6,7,7a-hexahydro-5*H*-inden-5-ol (6): $CeCl_3 \cdot 7H_2O$ (0.90 g, 2.42 mmol) was added to a solution of **5b** (0.90 g, 2.50 mmol) in methanol (15 mL) and THF (30 mL). After the salt had dissolved, the solution was cooled to 0 °C and $NaBH_4$ (0.12 g, 3.17 mmol) was added in portions. The mixture was stirred at 0 °C for 2 h and then acetone (3 mL) was added. After another 2 h the mixture was diluted with water (90 mL) and extracted with DCM (3 × 70 mL). The organic extract was dried and the solvent was evaporated. The residue was purified by chromatography on silica gel (30 g, 10% EtOAc/hexanes) to give **6** (0.84 g, 93%). M.p. 73–75 °C. $[\alpha]_D^{24}$ = +13.5 (*c* = 1.38). ^{1}H NMR (200 MHz): δ = 0.03 (s, 6 H, $Si(CH_3)_2$) 0.88 (s, 9 H, $C(CH_3)_3$) 1.02 (s, 3 H, CH_3), 1.16–1.44 (m, 1 H), 1.60–2.00 (m, 4 H), 2.11–2.41 (m, 4 H) 3.62 (dd, *J* = 10.2, 7.6 Hz, 1 H, 1-H), 4.18–4.33 (m, 1 H, 4-H) ppm. ^{13}C NMR (50 MHz): δ = –4.9, –4.4 ($Si(CH_3)_2$), 16.7 (CH_3), 18.0 ($C(CH_3)_3$), 25.8 ($C(CH_3)_3$), 27.8, 29.6, 29.7, 33.5, (C-2, C-3, C-6, C-7), 48.3 (C-7a), 71.7 (C-5), 81.1 (C-1), 121.8 (C-4), 148.0 (C-3a) ppm. $C_{16}H_{29}BrO_2Si$ (361.39): calcd. C 53.18, H 8.09, Br 22.11; found C 53.12, H 8.26, Br 21.80.

2-[(1*S*,5*R*,7a*S*)-4-Bromo-1-(*tert*-butyldimethylsilyloxy)-7a-methyl-2,3,5,6,7,7a-hexahydro-1*H*-inden-5-ylthio]-1,3-benzothiazole (7): Tributylphosphane (0.83 g, 1.02 mL, 4.10 mmol) was added followed by DIAD (0.83 g, 0.79 mL, 4.10 mmol) in THF (3 mL) to a solution of **6** (0.80 g, 2.21 mmol) and 1,3-benzothiazole-2-thiol (0.56 g, 3.35 mmol) in THF (19 mL) stirred at 0 °C. After 1 h the mixture was warmed to room temp. and left aside for an additional 1 h. Silica gel (2 g) was added and the solvent was evaporated in a rotary evaporator. The residue was transferred to a silica gel column (35 g). The column was eluted with 0.5% EtOAc in hexanes to give **7** (0.99 g, 88%). M.p. 104–105 °C (methanol). $[\alpha]_D^{22}$ = –35.2 (*c* = 1.07). ^{1}H NMR (200 MHz): δ = 0.04 (s, 6 H, $Si(CH_3)_2$) 0.88 (s, 9 H, $C(CH_3)_3$) 1.01 (s, 3 H, CH_3), 1.45–2.01 (m, 4 H), 2.21–2.60 (m, 4 H), 3.66 (dd, *J* = 10.0, 7.6 Hz, 1 H, 1-H), 4.88–4.95 (m, 1 H, 5-H), 7.24–7.47 (m, 2 H, aromatic-H), 7.72–7.80 (m, 1 H, aromatic-H), 7.84–7.92 (m, 1 H, aromatic-H) ppm. ^{13}C NMR (50 MHz): δ = –4.8, –4.5 ($Si(CH_3)_2$), 17.0 (CH_3), 18.0 ($C(CH_3)_3$), 25.8 ($C(CH_3)_3$), 28.5, 29.0, 29.5, 30.2, (C-2, C-3, C-6, C-7), 48.3 (C-7a), 54.0 (C-5), 80.9 (C-1), 113.9 (C-4), 120.9, 121.6, 124.3, 126.0 (4 aromatic C), 135.3, 150.9 (C-5), 153.2, 165.9 (N=C(-S)-S) ppm. $C_{23}H_{32}BrNOS_2Si$ (510.63): calcd. C 54.10, H 6.32, Br 15.65, N 2.74, S 12.56; found C 54.09, H 6.39, Br 15.74, N 2.79, S 12.32.

(1*S*,5*S*,7a*S*)-1-*tert*-Butoxy-7a-methyl-2,3,5,6,7,7a-hexahydro-1*H*-inden-5-ol (8): $CeCl_3 \cdot 7H_2O$ (0.49 g, 1.32 mmol) was added to (1*S*,7a*S*)-1-*tert*-butoxy-7a-methyl-1,2,3,6,7,7a-hexahydro-5*H*-inden-5-one[27] (0.30 g, 1.35 mmol) in methanol (10 mL) and THF (5 mL). After the salt had dissolved, the solution was cooled to 0 °C and $NaBH_4$ (60 mg, 1.59 mmol) was added. The mixture was stirred at 0 °C for 1 h and then acetone (2 mL) was added. After another 2 h water was added (30 mL) and the mixture was extracted with DCM (3 × 20 mL). The organic extract was dried and the solvent was evaporated to give **8** (0.30 g, 99%). M.p. 63–65 °C. ^{1}H NMR (200 MHz): δ = 0.99 (s, 3 H, CH_3), 1.14 (s, 9 H, $C(CH_3)_3$), 1.19–2.16 (m, 9 H), 2.34–2.56 (m, 1 H), 3.37 (t, *J* = 8.2 Hz, 1 H, 1-H), 4.16–4.34 (br., 1 H, 5-H), 5.28–5.36 (m, 1 H, 4-H) ppm. ^{13}C NMR (50 MHz): δ = 17.3 (CH_3), 26.0, 28.8 ($C(CH_3)_3$), 29.7, 29.8, 34.2, 43.3 (C-7a), 68.8 (C-5), 72.6 ($C(CH_3)_3$), 80.2 (C-1), 122.2 (C-4), 149.4 (C-3a) ppm, in agreement with data reported elsewhere.[28]

2-[(1*S*,5*R*,7a*S*)-1-*tert*-Butoxy-7a-methyl-2,3,5,6,7,7a-hexahydro-1*H*-inden-5-ylthio]-1,3-benzothiazole (9) and (1*S*,5*R*,7a*S*)-3-(1-*tert*-Butoxy-7a-methyl-2,3,5,6,7,7a-hexahydro-1*H*-inden-5-yl)-1,3-benzothiazole-2(3*H*)-thione (10): DEAD (0.28 g, 0.25 mL, 1.61 mmol) in THF (5 mL) was added dropwise to a solution of **8** (0.24 g, 1.07 mmol), tributylphosphane (0.33 g, 0.40 mL, 1.63 mmol) and 1,3-benzothiazole-2-thiol (0.20 g, 1.20 mmol) in THF (30 mL) stirred at –78 °C. After 1 h the mixture was warmed to room temp. and set aside for 12 h. The solvent was evaporated and the residue was purified by chromatography on silica gel (40 g, 1% EtOAc/hexanes) to give **9** (colorless oil, 0.30 g, 75%) and **10** (colorless crystals, 48 mg, 12%).

Benzothiazole 9: $[\alpha]_D^{24}$ = +50.8 (*c* = 0.97). ^{1}H NMR (200 MHz): δ = 0.97 (s, 3 H, CH_3), 1.16 (s, 9 H, $C(CH_3)_3$), 1.20–2.60 (m, 8 H), 3.45 (t, *J* = 8.8 Hz, 1 H, 1-H), 4.64–4.74 (br. s, 1 H, 5-H), 5.46–4.58 (br. s, 1 H, 4-H) 7.24–7.48 (m, 2 H, aromatic-H), 7.70–7.93 (m, 2 H, aromatic-H) ppm. ^{13}C NMR (50 MHz): δ = 17.1 (CH_3), 26.2 (CH_2), 26.5 (CH_2), 28.8 ($C(CH_3)_3$), 29.8 (CH_2), 30.8 (CH_2), 43.2 (C-7a), 45.8 (C-5), 72.7 (C-1), 80.4 ($C(CH_3)_3$), 116.4 (C-4), 120.9, 121.5, 124.2, 125.9 (4 aromatic C), 135.2, 151.4 (C-3a), 153.3, 166.8 (N=C(-S)-S) ppm. $C_{21}H_{27}NOS_2$ (373.58): calcd. C 67.52, H 7.28, N 3.75, S 17.17; found C 67.47, H 7.24, N 3.72, S 16.99.

Benzothiazole 10: M.p. 180–181 °C (acetone). $[\alpha]_D^{23}$ = +134.2 (*c* = 1.10). ^{1}H NMR (200 MHz): δ = 0.99 (s, 3 H, CH_3), 1.21 (s, 9 H, $C(CH_3)_3$), 1.30–2.70 (m, 8 H), 3.64 (dd, *J* = 9.6, 7.6 Hz, 1 H, 1-H), 5.48 (d, *J* = 1.6 Hz, 1 H, 5-H), 6.22–6.41 (m, 1 H, 4-H), 7.18–7.35 (m, 2 H, aromatic-H), 7.49–7.50 (m, 1 H, aromatic-H), 7.55–7.65 (m, 1 H, aromatic-H) ppm. ^{13}C NMR (50 MHz): δ = 16.8 (CH_3), 24.4 (CH_2), 26.2 (CH_2), 28.8 ($C(CH_3)_3$), 29.9 (CH_2), 31.5 (CH_2), 43.0, (C-7a), 52.8 (C-5), 72.7 (C-1), 79.2 ($C(CH_3)_3$), 113.8, 117.1, 121.0, 124.0 (4 aromatic C), 125.9 (C-4), 127.3, 141.3, 150.6 (C-3a), 189.2 (C=S) ppm. $C_{21}H_{27}NOS_2$ (373.57): calcd. C 67.52, H 7.28, N 3.75, S 17.17; found C 67.87, H 7.25, N 3.80, S 17.36.

2-(4-Bromocholest-4-en-3α-ylsulfonyl)-1,3-benzothiazole (11a): $KMnO_4$ (0.72 g, 4.56 mmol) and $FeCl_3 \cdot 6H_2O$ (0.72 g, 2.66 mmol) were added to a solution of **2a** (0.67 g 1.09 mmol) in methyl ethyl ketone (30 mL) stirred at room temp. After 1 h the solvent was evaporated. The residue was taken up in DCM (30 mL) and filtered through a pad of Celite. The filtrate was washed with water (50 mL) and dried. The solvent was evaporated and the residue was triturated with hexanes (10 mL) and filtered to give **11a** (0.44 g, 62%). M.p. 217–219 °C (acetone). $[\alpha]_D^{23}$ = +258.8 (*c* = 0.97). ^{1}H NMR (400 MHz): δ = 0.63 (s, 3 H, 18-H), 0.87 and 0.88 (2d, *J* = 6.6 Hz, 6 H, 26-H, 27-H), 0.90 (d, *J* = 6.7 Hz, 3 H, 21-H), 1.05 (s, 3 H, 19-H) overlapping 0.55–2.20 (m, 26 H), 2.70–2.90 (m, 2 H), 4.60–4.70 (br. s, 1 H, 3-H), 7.48–7.68 (m, 2 H, aromatic-H), 7.97–8.06 (m, 1 H, aromatic-H), 8.20–8.28 (m, 1 H, aromatic-H) ppm. $C_{34}H_{48}BrNO_2S_2$ (646.78): calcd. C 63.13, H 7.50, N 2.17, S 9.92, Br 12.35; found C 63.03, H 7.53, N 2.00, S 9.91, Br 12.22.

2-(Cholest-4-en-3α-ylsulfonyl)-1,3-benzothiazole (11b): $KMnO_4$ (1.08 g, 6.83 mmol) and $FeCl_3 \cdot 6H_2O$ (1.08 g, 4.00 mmol) were

added to a solution of **2b** (0.90 g, 1.68 mmol) in ethyl methyl ketone (45 mL), stirred at room temp. After 1 h the solvent was evaporated. The residue was taken up in DCM (50 mL) and filtered through a pad of Celite. The filtrate was washed with water (70 mL) and dried. The solvent was evaporated and the residue was triturated with hexanes (15 mL). The solid was collected to give sulfone **11b** (0.67 g, 70%). M.p. 225–228 °C (DCM/acetone). $[\alpha]_D^{23}$ = +150.9 (c = 0.37). ^{1}H NMR (400 MHz): δ = 0.51 (dt, J = 12.1, 4.3 Hz, 2 H), 0.62 (s, 3 H, 18-H), 0.64–0.84 (m, 2 H), 0.87 and 0.88 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.89 (d, J = 6.6 Hz, 3 H, 21-H), 1.05 (s, 3 H, 19-H) overlapping 0.91–1.06 (m, 3-H), 1.07–1.40 (m, 10 H), 1.42–1.58 (m, 3 H), 1.60–1.99 (m, 5 H), 2.01–2.37 (m, 3 H), 4.17 (sym. m, 1 H, 3-H), 5.46 (d, J = 4.5 Hz, 1 H, 4-H), 7.57–7.66 (m, 2 H, aromatic-H), 8.00–8.04 (m, 1 H, aromatic-H), 8.22–8.27 (m, 1 H, aromatic-H) ppm. $C_{34}H_{49}NO_2S_2$ (567.89): calcd. C 71.90, H 8.69, N 2.46, S 11.29; found C 71.90, H 8.79, N 2.48, S 11.35.

2-[(1*S*,5*R*,7a*S*)-4-Bromo-1-(*tert*-butyldimethylsilyloxy)-7a-methyl-2,3,5,6,7,7a-hexahydro-1*H*-inden-5-ylsulfonyl]-1,3-benzothiazole (12a): *m*-CPBA (70%, 0.44 g, 1.80 mmol) in DCM (6 mL) was added dropwise to a stirred solution of **7** (0.40 g, 0.78 mmol) in DCM (6 mL) containing powdered $NaHCO_3$ (0.30 g, 3.57 mmol). After 24 h water (80 mL) was added and the mixture was extracted with DCM (3 × 50 mL). The organic extract was washed consecutively with aqueous $Na_2S_2O_3$, $NaHCO_3$ and brine, dried and the solvent was evaporated. The residue was purified by chromatography on silica gel (15 g, 4% EtOAc/hexanes) to give **12a** (0.35 g, 82%). M.p. 143–144 °C (pentane). $[\alpha]_D^{23}$ = +186.6 (c = 0.96). ^{1}H NMR (200 MHz): δ = 0.006 and 0.011 (2s, 6 H, $Si(CH_3)_2$), 0.87 (s, 9 H, $C(CH_3)_3$) 0.99 (s, 3 H, CH_3), 1.60–2.00 (m, 4 H), 2.20–2.42 (m, 3 H), 2.82–2.96 (m, 1 H), 3.67 (dd, J = 9.8, 7.8 Hz, 1 H, 1-H), 4.65–4.75 (m, 1 H, 5-H), 7.53–7.69 (m, 2 H, aromatic-H), 7.96–8.05 (m, 1 H, aromatic-H), 8.17–8.26 (m, 1 H, aromatic-H) ppm. ^{13}C NMR (50 MHz): δ = –4.9, –4.5 ($Si(CH_3)_2$), 17.0 (CH_3), 18.0 ($C(CH_3)_3$) 22.6 (CH_2), 25.7 ($C(CH_3)_3$), 28.9 (CH_2), 29.5 (CH_2), 30.1 (CH_2), 48.5 (C-7a), 68.2 (C-5), 80.2 (C-1), 105.1 (C-4), 122.3, 125.4, 127.5, 127.8 (4 aromatic C), 137.1, 152.6 (C-3a), 155.7, 167.4 (N=C(-S)-S) ppm. $C_{23}H_{33}BrNO_3S_2Si$ (542.62): calcd. C 50.91, H 5.94, Br 14.73, N 2.58, S 11.82; found C 50.89, H 5.97, Br 14.70, N 2.45, S 11.71.

2-[(1*S*,5*R*,7a*S*)-1-*tert*-Butoxy-7a-methyl-2,3,5,6,7,7a-hexahydro-1*H*-inden-5-ylsulfonyl]-1,3-benzothiazole (12b): A solution of *m*-CPBA (70%, 0.30 g, 1.22 mmol) in DCM (5 mL) was added dropwise over 15 min to a stirred solution of **9** (0.21 g, 0.56 mmol) in DCM (10 mL) containing powdered $NaHCO_3$ (0.50 g, 5.95 mmol). After 4 h, water (80 mL) was added and the mixture was extracted with DCM (3 × 50 mL). The organic extract was washed consecutively with aq. $Na_2S_2O_3$, aq. $NaHCO_3$ and brine, dried and the solvents evaporated. The residue was purified by chromatography on silica gel (10 g, 10% EtOAc/hexanes) to give **12b** (0.16 g. 70%). M.p. 124–126 °C (pentane/acetone). $[\alpha]_D^{29}$ = +155.5 (c = 1.16). ^{1}H NMR (200 MHz): δ = 0.90 (s, 3 H, CH_3), 1.04 (s, 9 H, $C(CH_3)_3$), 1.16–2.61 (m, 8 H), 3.26 (t, J = 8.2, Hz, 1 H. 1-H), 4.15–4.28 (m, 1 H, 5-H), 5.50–5.58 (br. s, 1 H, 4-H), 7.54–7.69 (m, 2 H, aromatic-H), 7.97–8.06 (m, 1 H, aromatic-H), 8.18–8.28 (m, 1 H, aromatic-H) ppm. ^{13}C NMR (50 MHz): δ = 17.0 (CH_3), 19.1 (CH_2), 26.7 (CH_2), 28.5 ($C(CH_3)_3$), 29.5 (CH_2), 30.1 (CH_2), 42.7 (C-7a), 60.8 (C-5), 72.5 (C-1), 79.7 ($C(CH_3)_3$), 107.4 (C-4), 122.1, 125.2, 127.4, 127.7 (4 aromatic C), 136.8, 152.5, 156.9 (C-3a), 165.2 (N=C(-S)-S) ppm. $C_{21}H_{27}NO_3S_2$ (405.58): calcd. C 62.19, H 6.71, N 3.45, S 15.81; found C 62.23, H 6.74, N 3.39, S 15.86.

4-Bromo-5α-cholest-3-ene (14a) from 11a: $NaBH_4$ (38 mg, 1.00 mmol) was added to a solution of **11a** (0.34 g, 0.53 mmol) in THF (12 mL) and ethanol (12 mL) stirred at room temp. After 18 h, the solvent was evaporated under reduced pressure at room temp. DCM (25 mL) was added to the residue and the mixture was brought to reflux (preheated oil bath) and then aqueous 0.9 M tartaric acid (5 mL) was added dropwise. Vigorous gas evolution occurred. After 30 min the mixture was cooled and extracted with hexanes (3 × 50 mL). The organic extract was dried and the solvent was evaporated. The residue was purified by chromatography on silica gel (10 g, hexanes) to give **14a** (0.22 g, 92%, 95% pure by GC). M.p. 96–97 °C (acetone). $[\alpha]_D^{23}$ = +5.3 (c = 1.03). ^{1}H NMR (400 MHz): δ = 0.66 (s, 3 H, 18-H), 0.69–0.77 (m, 1 H), 0.85 (s, 3 H, 19-H), 0.86 and 0.87 (2d, J = 6.7 Hz, 6 H, 26-H, 27-H), 0.89 (d, J = 7.3 Hz, 3 H, 21-H) overlapping 0.90–1.61 (m, 20 H), 1.70–1.89 (m, 3 H), 1.92–2.13 (m, 5 H), 6.00–6.07 (m, 1 H, 3-H) ppm. $C_{27}H_{45}Br$ (449.55): calcd. C 72.14, H 10.09, Br 17.77; found C 72.13, H 10.03, Br 17.68. GC analysis: R_{t1} = 30.95 min (4.49%), R_{t2} = 31.78 min (0.40%), R_{t3} = 34.89 min (95.11%).

5α-Cholest-3-ene (14b) from 11b: $NaBH_4$ (60 mg, 1.59 mmol) was added to a solution of **11b** (0.60 g, 1.06 mmol) in THF (24 mL) and ethanol (24 mL) stirred at room temp. After 18 h the solvent was evaporated at room temp. under reduced pressure. DCM (40 mL) was added to the residue. The mixture was brought to reflux (oil bath) and 0.9 M aqueous tartaric acid (10 mL) was added dropwise. Vigorous evolution of a gas occurred. After 30 min the mixture was cooled and extracted with hexanes (3 × 50 mL). The extract was dried and the solvents evaporated. The residue was purified by chromatography on silica gel (10 g, hexanes) to give **14b** (0.38 g, 97%). M.p. 74–76 °C. ^{1}H NMR (200 MHz): δ = 0.66 (s, 3 H, 18-H), 0.77 (s, 3 H, 19-H), 0.861 and 0.864 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.90 (d, J = 8.2 Hz, 3 H, 21-H), 1.00–2.20 (m, 29 H), 5.20–5.26 (m, 1 H, 4-H), 5.49–5.60 (m, 1 H, 3-H) ppm. GC: R_{t1} = 22.12 min (5.48%), R_{t2} = 23.35 (92.72%), R_{t3} = 24.02 min (1.80%).

(1*S*,3a*R*,7a*S*)-4-Bromo-7a-methyl-2,3,3a,6,7,7a-hexahydro-1*H*-inden-1-ol (16) and (1*S*,3a*S*,7a*S*)-4-Bromo-7a-methyl-2,3,3a,6,7,7a-hexahydro-1*H*-inden-1-ol (17): $NaBH_4$ (15 mg. 0.40 mmol) was added to a solution of **12a** (200 mg, 0.36 mmol) in ethanol (5 mL). After 16 h the solvent was evaporated. CH_2Cl_2 (40 mL) was added to the residue and the mixture was heated at 50–60 °C (oil bath) while aqueous 0.9 M tartaric acid (3 mL) was added dropwise. After gas evolution had ceased, water (20 mL) was added. The organic layer was separated. The aqueous layer was washed with DCM (2 × 10 mL). The combined organic extracts were dried and the solvent evaporated. The residue was purified by chromatography on silica gel (7 g, hexanes) to give the main fraction consisting of two compounds (97 mg 77%). Part of this product (60 mg) was dissolved in THF (3 mL) and TBAF·$3H_2O$ (101 mg, 0.32 mmol) was added to the solution. The mixture was stirred at room temp. for 24 h and then silica gel (0.2 g) was added and the solvent was evaporated. The residue was transferred to a silica gel column (3 g) and the column was eluted with 5% EtOAc in hexanes to give **16** (28 mg, 71%) and **17** (9 mg, 22%).

Inden-1-ol 16: $[\alpha]_D^{24}$ = –15.5 (c = 1.715). ^{1}H NMR (500 MHz): δ = 0.84 (d, J = 0.7 Hz, 3 H, CH_3), 1.32–1.40 (m, 1 H, CH_2), 1.48–1.57 (m, 1 H, CH_2), 1.58–1.66 (m, 2 H, CH_2, OH), 1.73–1.81 (m, 1 H, CH_2), 1.81–1.86 (dt, J = 12.6, 4.10 Hz, 1 H, CH_2), 2.10–2.17 (m, 1 H, CH_2), 2.17–2.22 (m, 2 H, CH_2), 2.36–2.43 (m, 1 H, 3aH), 3.78 (dd, J = 9.1, 7.6 Hz, 1 H, 1-H), 5.90 (q, J = 3.5 Hz, 1 H, 5-H) ppm. ^{13}C NMR (125 MHz): δ = 10.6 (CH_3), 25.0, 26.5, 29.9, 32.5 (C-2, C-3, C-6, C-7), 45.3 (C-7a), 48.9 (C-3a), 80.2 (C-1), 123.2 (C-4), 127.3 (C-5) ppm. HRMS: calcd. for $C_{10}H_{15}{}^{79}BrO$: 230.03063; found 230.02998.

Inden-1-ol 17: M.p. 45–46 °C (pentane). $[\alpha]_D^{23}$ = +29.0 (c = 0.735). ^{1}H NMR (500 MHz): δ = 1.02 (s, 3 H, CH_3), 1.27–1.34 (m, 1 H, CH_2), 1.36–1.43 (m, 1 H, CH_2), 1.43–1.47 (br. s, 1 H, OH), 1.52–1.64 (m, 2 H, CH_2), 2.02–2.10 (m, 1 H, CH_2), 2.10–2.20 (m, 2 H, CH_2), 2.22–2.31 (m, 1 H, CH_2), 2.51 (br. t, J = 8.7 Hz, 1 H, 3a-H), 3.84, (dd, J = 5.8, 4.2 Hz, 1 H, 1-H), 5.93–5.96 (m, 1 H, 5-H) ppm. ^{13}C NMR (125 MHz): δ = 18.6 (CH_3), 24.4, 28.5, 29.0, 31.7 (C-2, C-3, C-6, C-7), 46.3 (C-7a), 51.9 (C-3a), 80.0 (C-1), 126.4 (C-5), 127.3 (C-4) ppm. $C_{10}H_{15}BrO$ (231.13): calcd. C 51.97, H 6.54, Br 34.5; found C 52.20, H 6.58, Br 34.58. HRMS: calcd. for $C_{10}H_{15}{}^{79}BrO$ $[M]^+$: 230.03063; found 230.03172.

Attempted Preparation of (1*S*,3a*S*,7a*S*)-1-*tert*-Butoxy-7a-methyl-2,3,3a,6,7,7a-hexahydro-1*H*-indene from 12b: $NaBH_4$ (28 mg, 0.74 mmol) was added to a solution **12b** (250 mg, 0.62 mmol) in THF (10 mL) and ethanol (10 mL). The mixture was stirred at room temp. for 12 h and then the solvent was evaporated and the residue was triturated with DCM (40 mL). The slurry was brought to boiling and 0.9 M aqueous tartaric acid (6 mL) was added dropwise. Vigorous gas evolution occurred. After 0.5 h water (20 mL) was added and the mixture was extracted with DCM (3 × 15 mL). The organic extract was dried and the solvent was evaporated. The residue was purified by chromatography on silica gel (10 g, 1% EtOAc/hexanes) to give a mixture of isomers (63 mg, 48%). All attempts to separate this mixture by chromatography failed.

4-Bromocholest-4-ene-3α-thiol (18a): BH_3·THF (1 M, 2 mL, 2.00 mmol) was added dropwise to a solution of sulfide **2a** (615 mg, 1.00 mmol) in THF (15 mL) stirred at –15 °C. After 1 h $LiAlH_4$ (100 mg, 2.6 mmol) was added. The mixture was stirred at –15 °C for a further 3 h and then the excess reagent was quenched with saturated aq. Na_2SO_4. The solid was filtered off and washed with diethyl ether (25 mL). The combined filtrates were evaporated and the residue was purified by chromatography on silica gel (25 g, pentane) to give **18a** (376 mg, 78%). M.p. 71–73 °C (acetone). $[\alpha]_D^{25}$ = +169.8 (c = 1.045). ^{1}H NMR (400 MHz): δ = 0.68 (s, 3 H, 18-H), 0.86 and 0.87 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.90 (d, J = 6.4 Hz, 3 H, 21-H), 0.94–1.05 (m, 2 H), 1.06 (s, 3 H, 19-H) overlapping 1.07–1.19 (m, 4 H), 1.20–1.46 (m, 8 H), 1.46 –1.61 (m, 4 H), 1.61–1.89 (m, 6 H), 1.94–2.05 (m, 2 H), 2.23–2.28 (m, 2 H), 2.87 (ddd, J = 13.8, 4.0, 2.8 Hz, 1 H), 3.83 (br. t, J = 5.7 Hz, 1 H, 3-H) ppm. ^{13}C NMR (100 MHz): δ = 11.9, 18.6, 19.4, 21.5, 22.5, 22.8, 23.8, 24.1, 28.0, 28.2, 28.9, 30.8, 31.5, 32.3, 35.6, 35.8, 36.1, 39.5, 39.7, 41.4, 42.4, 45.6, 54.6, 55.8, 56.1, 121.3, 144.3 ppm. $C_{27}H_{45}BrS$ (481.62): calcd. C 67.34, H 9.42, Br 16.59, S 6.66; found C 67.57, H 9.44, Br 16.84, S 6.64.

Rechromatography of the more polar fractions gave *N*-methyl-2-(2-methylaminophenyldisulfanyl)aniline (**20**): ^{1}H NMR (200 MHz): δ = 2.78 (s, 3 H, CH_3), 2.80 (s, 3 H, CH_3) 4.8–5.0 (br., 2 H, N-H), 6.46–6.64 (m, 4 H, aromatic-H), 7.11–7.31 (m, 4 H, aromatic-H) ppm. ^{13}C NMR (50 MHz): δ = 30.3, 109.7, 116.1, 118.4, 132.0, 137.0, 150.3 ppm, in agreement with data previously reported.[21] LRMS (EI): m/z = 276 $[M]^+$.

Cholest-4-ene-3α-thiol (18b): BH_3·THF (1 M, 2 mL, 2.00 mmol) was added dropwise to a solution of sulfide **2b** (536 mg, 1.00 mmol) in THF (15 mL) stirred at –15 °C. After 1 h $LiAlH_4$ (100 mg, 2.6 mmol) was added and the mixture was stirred at –15 °C for a further 3 h. The excess reagent was quenched with saturated aqueous Na_2SO_4. The precipitate was filtered off and washed with diethyl ether (25 mL). The combined filtrates were evaporated and the residue was purified by chromatography on silica gel (20 g, pentane) to give **18b** (270 mg, 67%). M.p. 81–83 °C (acetone). $[\alpha]_D^{26}$ = +223.4 (c = 1.025). ^{1}H NMR (400 MHz): δ = 0.68 (s, 3 H, 18-H), 0.86 and 0.87 (2d, J = 6.6 Hz, 6 H, 26-H, 27-H), 0.91, (d, J = 6.6 Hz, 3 H, 21-H), 0.99 (s, 3 H, 19-H) overlapping 0.76–1.06 (m, 2 H), 1.08 –1.45 (m, 11 H), 1.48–1.74 (m, 10 H), 1.77–1.87 (m, 2 H), 1.93–2.06 (m, 3 H), 2.12–2.23 (m, 1 H), 3.51–3.58 (m, 1 H, 3-H), 5.40 (d, J = 4.8 Hz, 1 H, 4-H) ppm. ^{13}C NMR (100 MHz): δ = 12.0, 18.6, 18.9, 21.5, 22.6, 22.8, 23.8, 24.2, 28.0, 28.2, 28.9, 32.1, 32.3, 32.8, 35.4, 35.8, 35.9, 36.1, 37.2, 39.5, 39.9, 42.5, 54.3, 56.1, 56.2, 121.8, 146.6 ppm. $C_{27}H_{46}S$ (402.72): calcd. C 80.52, H 11.51, S 7.96; found C 80.56, H 11.52, S 8.06.

(1*S*,5*R*,7a*S*)-4-Bromo-7a-methyl-1-(*tert*-butyldimethylsilyloxy)-2,3,5,6,7,7a-hexahydro-1*H*-indene-5-thiol (19a): BH_3·THF (1 M, 4.3 mL, 4.3 mmol) was added dropwise to a solution of sulfide **7** (1.10 g, 2.15 mmol) in THF (30 mL) stirred at –15 °C. After 1 h $LiAlH_4$ (225 mg, 5.89 mmol) was added and the mixture was left at –15 °C for a further 3 h. The reagent excess was quenched with saturated aq. Na_2SO_4. The solid was filtered off and washed with diethyl ether (20 mL). The combined filtrates were evaporated. The residue was purified by chromatography on silica gel (15 g, pentane) to give thiol **19a** (594 mg, 73%). M.p. 36–40 °C (methanol/pentane). $[\alpha]_D^{22}$ = +130.5 (c = 0.39). ^{1}H NMR (400 MHz): δ = 0.037 and 0.044 (2s, 6 H, $Si(CH_3)_2$), 0.89 (s, 9 H, $C(CH_3)_3$), 0.95 (d, J = 0.4 Hz, 3 H, CH_3), 1.56–1.74 (m, 3 H), 1.84–2.02 (m, 2 H), 2.20–2.41 (m, 4 H), 3.67 (dd, J = 9.9, 7.7 Hz, 1 H, 1-H), 3.78–3.82 (m, 1 H, 5-H) ppm. ^{13}C NMR (100 MHz): δ = –4.8, –4.5 ($Si(CH_3)_3$), 17.0 (CH_3), 18.0 ($C(CH_3)_3$), 25.7 ($C(CH_3)_3$), 28.1, 29.2, 29.5, 29.9 (C-2, C-3, C-6, C-7), 43.4 (C-5), 48.1 (C-7a), 81.0 (C-1), 120.0 (C-4), 146.1 (C-3a) ppm. $C_{16}H_{29}BrOSSi$ (377.45): calcd. C 50.91, H 7.74, Br 21.17, S 8.50; found C 51.10, H 7.83, Br 21.18, S 8.57.

(1*S*,5*R*,7a*S*)-1-*tert*-Butoxy-7a-methyl-2,3,5,6,7,7a-hexahydro-1*H*-indene-5-thiol (19b): BH_3·THF (1 M, 3.6 mL, 3.6 mmol) was added dropwise to a solution of sulfide **9** (669 mg, 1.78 mmol) in THF (24 mL) stirred at –15 °C. After 1 h $LiAlH_4$ (183 mg, 4.8 mmol) was added and the mixture was stirred at –15 °C for a further 3 h. The excess reagent was quenched with saturated aq. Na_2SO_4. The solid was filtered off and washed with diethyl ether (15 mL). The combined filtrates were evaporated and the residue was purified by chromatography on silica gel (10 g, pentane) to give thiol **19b** (250 mg, 58%). ^{1}H NMR (400 MHz): δ = 0.91 (s, 3 H, CH_3), 1.17 (s, 9 H, $C(CH_3)_3$), 1.50 (dt, J = 13.3, 2.9 Hz, 1 H), 1.56–1.72 (m, 2 H), 1.74–1.82 (m, 1 H), 1.83–1.93 (m, 2 H), 2.04–2.19 (m, 2 H), 2.38–2.49 (m, 1 H), 3.43 (t, J = 8.8 Hz, 1 H, 1-H), 3.60–3.68 (m, 1 H, 5-H), 5.37–5.42 (m, 1 H, 4-H) ppm. ^{13}C NMR (100 MHz): δ = 17.1 (CH_3), 26.2 (CH_2), 28.8 ($C(CH_3)_3$), 29.1 (CH_2), 29.5 (CH_2), 29.9 (CH_2), 35.4 (C-5), 42.9 (C-7a), 72.6 ($C(CH_3)_3$), 80.6 (C-1), 121.4 (C-4), 146.6 (C-3a) ppm. HRMS (EI): calcd. for $C_{14}H_{24}OS$ $[M]^+$: 240.15479; found 240.15374.

4-Bromo-5α-cholest-3-ene (14a) from 18a

Method A: Thiol **18a** (120 mg, 0.25 mmol) in DCM (2 mL) was added to a solution of oxaziridine **21** (144 mg, 0.54 mmol) in DCM (1 mL) stirred at 0 °C. The mixture was set aside at room temp. for 3 h and then the solvent was evaporated using a rotary evaporator (water bath temp. 40–50 °C). The residue was purified by chromatography on silica gel (2 g, pentane) to give **14a** (100 mg, 89%). GC analysis: R_{t1} = 31.18 min (1.46%), R_{t2} = 34.89 min (98.54%).

Method B: BuLi (2.0 M in hexanes, 0.19 mL, 0.38 mmol) was added dropwise to a solution of thiol **18a** (173 mg, 0.36 mmol) in THF (1 mL) stirred at –78 °C. After 15 min a solution of **21** (207 mg, 0.79 mmol) in THF (0.8 mL) was added dropwise. The mixture was stirred at –78 °C for 30 min, warmed to room temp. and then left for an additional 1 h. The cloudy solution was evaporated to give an amorphous residue. DCM (5 mL) was added and the mixture was brought to gentle reflux (oil bath). An aqueous solution of

tartaric acid (0.9 M, 2 mL) was added dropwise to this mixture. The mixture was heated under reflux for a further 25 min, cooled and water (10 mL) was added. The layers were separated and an aqueous layer was extracted with hexanes (3 × 10 mL). The combined organic extracts were dried and the solvents evaporated. The residue was purified by chromatography on silica gel (2 g, hexanes) to give **14a** (43 mg, 26%).

5α-Cholest-3-ene (14b) from 18b

Method A: A solution of thiol **18b** (201 mg, 0.50 mmol) in DCM (3 mL) was added to a solution of oxaziridine **21** (287 mg, 1.09 mmol) in DCM (2 mL) stirred at 0 °C. The mixture was set aside at room temp. for 3 h and then the solvent was evaporated using a rotary evaporator (water bath temp. 40–50 °C). The residue was purified by chromatography on silica gel (3 g, pentane) to give **14b** (106 mg, 57%) contaminated with some diene. GC: R_{t1} = 23.92 min (92.28%), R_{t2} = 24.46 min (7.24%).

Method B: BuLi (2.0 M in hexanes, 0.19 mL, 0.38 mmol) was added dropwise to a solution of thiol **18b** (147 mg, 0.36 mmol) in THF (1 mL) stirred at –78 °C. After 15 min a solution of **21** (207 mg, 0.79 mmol) in THF (0.8 mL) was added dropwise. The mixture was stirred at –78 °C for 30 min, warmed to room temp. and left for an additional 1 h. The cloudy solution was evaporated. DCM (5 mL) was added to the residue and the mixture was brought to reflux (oil bath). Aqueous tartaric acid (0.9 M, 2 mL) was added dropwise. The mixture was refluxed for 25 min, cooled and then water (10 mL) was added. The layers were separated. The aqueous layer was extracted with hexanes (3 × 10 mL). The combined organic extracts were dried and the solvent was evaporated. The residue was purified by chromatography on silica gel (2 g, hexanes) to give **14b** (39 mg, 29%).

(1*S*,3a*R*,7a*S*)-4-Bromo-7a-methyl-2,3,3a,6,7,7a-hexahydro-1*H*-inden-1-yl (*tert*-Butyl)dimethylsilyl Ether (22a) from 19a: A solution of thiol **19a** (100 mg, 0.26 mmol) in DCM (7 mL) was added dropwise to a solution of oxaziridine **21** (150 mg, 0.57 mmol) in DCM (2 mL) stirred at 0 °C. The mixture was left at room temp. for 3 h. The solvent was evaporated using a rotary evaporator (bath temp. 40–50 °C). The residue was purified by chromatography on silica gel (2 g, pentane) to give **22a** (62 mg, 67%) contaminated with traces of dienes. For the analytical data, see below.

***tert*-Butyl (1*S*,3a*S*,7a*S*)-7a-Methyl-2,3,3a,6,7,7a-hexahydro-1*H*-inden-1-yl Ether (22b) from 19b:** A solution of thiol **19b** (53 mg, 0.22 mmol) in DCM (2 mL) was added dropwise to a solution of oxaziridine **21** (126 mg, 0.48 mmol) in DCM (1 mL) stirred at 0 °C. The mixture was set aside for 3 h at room temp. and then the solvent was evaporated using a rotary evaporator (bath temp. 40–50 °C). The residue was purified by chromatography on silica gel (1.5 g, pentane) to give **22b** contaminated with dienes (21 mg, 46%). Attempted purification of this compound failed.

(1*S*,3a*R*,7a*S*)-4-Bromo-7a-methyl-2,3,3a,6,7,7a-hexahydro-1*H*-inden-1-yl (*tert*-butyl)dimethylsilyl Ether (22a) from 19a via Lithium Thiolate: BuLi (2.0 M in hexanes, 0.19 mL, 0.38 mmol) was added dropwise to a solution of thiol **19a** (135 mg, 0.36 mmol) in THF (1 mL) stirred at –78 °C. After 15 min a solution of **21** (207 mg, 0.79 mmol) in THF (0.8 mL) was added dropwise. The mixture was kept at –78 °C for 30 min, warmed to room temp. and left for an additional 1 h. The cloudy solution was evaporated and DCM (5 mL) was added. The mixture was brought to gentle reflux (oil bath). Aqueous tartaric acid (0.9 M, 2 mL) was added dropwise. After 30 min the mixture was cooled and then water (8 mL) was added. The layers were separated and the aqueous layer was extracted with hexanes (3 × 10 mL). The combined organic extracts were dried and the solvents evaporated. The residue was purified by chromatography on silica gel (2 g, hexanes) to give **22a** (58–73 mg, 46–58%). $[\alpha]_D^{22}$ = +1.4 (*c* = 1.65). ^{1}H NMR (400 MHz): δ = 0.01 (s, 6 H, $Si(CH_3)_2$), 0.81 (d, *J* = 0.7 Hz, 3 H, CH_3), 0.88 (s, 9 H, $C(CH_3)_3$), 1.23–1.33 (m, 1 H), 1.48–1.66 (m, 2 H), 1.68–1.79 (m, 2 H), 1.91–2.01 (m, 1 H), 2.15–2.22 (m, 2 H), 2.31–2.39 (m, 1 H, 3a-H), 3.66–3.72 (m, 1 H, 1-H), 5.88 (q, *J* = 3.5 Hz, 1 H, 5-H) ppm. ^{13}C NMR (100 MHz): δ = –4.9, –4.5 ($Si(CH_3)_2$), 10.9 (CH_3), 18.0 ($C(CH_3)$), 25.2 ($C(CH_3)_3$), 25.8, 26.6, 30.3, 32.9 (C-2, C-3, C-6, C-7), 45.7 (C-7a), 48.5, (C-3a), 80.2 (C-1), 123.7 (C-4), 127.4 (C-5) ppm. $C_{16}H_{29}BrOSi$ (345.39): calcd. C 55.64, H 8.46, Br 23.13; found C 55.42, H 8.51, Br 23.09. HRMS (EI): calcd. for $C_{16}H_{29}O^{79}BrSi$ $[M]^+$ 344.11711; found 344.11823.

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