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Enantioselective PTC : Varying the Cinchona Alkaloid Motive[1]

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Abstract: Enantiopure phase transfer catalysts **3a-j**, **4a-j**, **5**, **8a-j**, **9a,b**, **10a,b** were prepared which represent changes in the fundamental structure of the alkaloids. These were tested in three enantioselective model reactions. It turned out that both the quinoline group carrying side arm and the quinuclidine core are important features of PT catalysts for highly enantioselective reactions.

A critical review of enantioselective phase transfer catalysis (PTC) [2-4] shows that cinchona alkaloid derived catalysts range among the most selective ones or even are the best in quite a number of reactions. Among these are various alkylations [5-9] , aldol reactions between silyl enol ethers and aldehydes [10], epoxidations of unsaturated ketones [11], hydroxylations of ketones *via* peroxygenation of the enolate anions [12], borohydride reductions [13], Darzens condensations [14], and Michael additions [15,16]. Common to all these successful applications is that the reaction conditions have to be optimized time consumingly and that these have a narrow scope. Structures of substrate, reagent, and catalyst must "fit together": A seemingly slight substituent variation in either of the three might transform a useful, high e.e. transformation into a total failure. Thus, enantioselective PTC is still in an early stage of development.

As part of a program to test new enantiopure PT catalysts [17,18] we try to find out which parts of the cinchona skeleton tolerate some variation and which ones are essential for the enantioselective action. Our first experiments are related to a removal and/or change of the quinoline carrying part of the molecules and to a differently substituted quinuclidine core. Further variations are under development.

H. M. R. Hoffmann and coworkers descibed recently a novel type of degradation of quinine and quinidine to (2S,5R) or (2R,5R)-2-hydroxymethyl-5-vinylquinuclidine (**1** or **2**, respectively) [19]. N-Alkylations transformed these into the two series of catalysts **3** and **4**. The alkyl groups were selected from those used in previous PTC studies. A specially substituted derivative (**5**) was prepared from **1** by consecutive O-alkylation (with 1-chloromethylnaphthalene) and N-alkylation (with 4-bromobenzyl bromide). Here the naphthalene residue is to mimic the quinoline part.

* e-mail : dehmlow@post.uni-bielefeld.de ‡ x-ray structure determination

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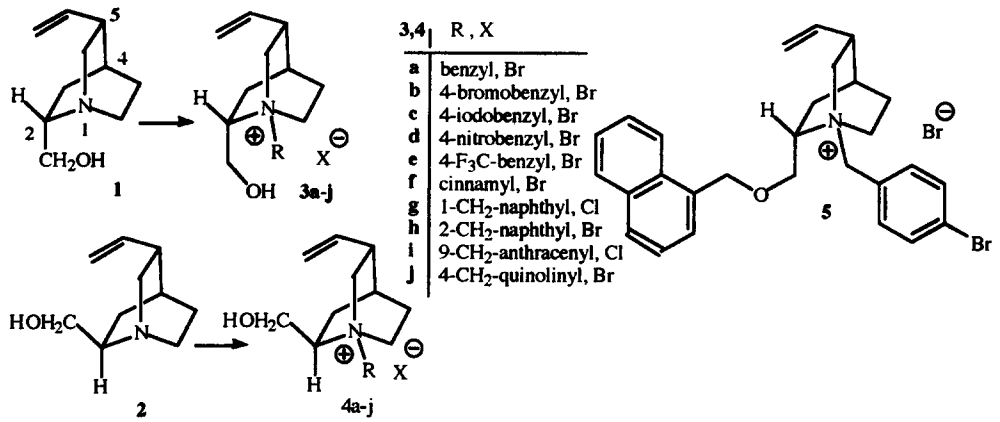
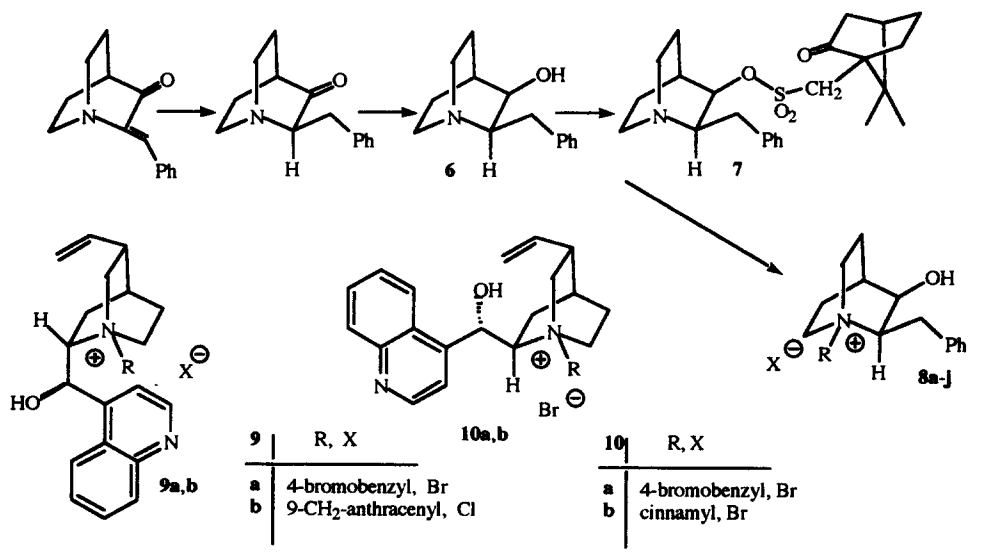


A second class of new catalysts comprises derivatives of cis-2-benzyl-3-hydroxyquinulidine (**6**). In earlier papers [20,21], this racemic compound was obtained along with its trans isomer by different hydrogenations of the corresponding α,ß-unsaturated ketone. In our hands difficult-to-separate mixtures with the trans isomer were formed under these conditions. In addition, we were unable to reproduce the reported direct diastereoselective synthesis of the trans isomer by $LiAlH_4$ reduction of 2-benzylidene-3-quinuclidone. We improved on the reductive process by first preparing 2-benzyl-3-quinuclidone [20]. Its subsequent Meerwein-Ponndorf reduction yielded a 16 : 1 mixture of **rac-6** and its epimer which could be separated easily by crystallization. Enantiomer separation was effected *via* salt formation with (S)-pyroglutamic acid and repeated crystallization. In a efford to verify the cis stereochemistry and to determine the absolute configuration, regenerated **6** was transformed into the ester with (1S)-10-camphorsulfonic acid (**7**) for an x-ray structural analysis. The ORTEP drawing of **7** is shown in figure 1. It indicates that the configuration of **6** is (2R,3R). Conversion of **6** with the alkyl halides used before provided the PT catalysts **8a-j**. -Finally, alkylation of cinchonidine and cinchonine furnished compounds **9a,b** and **10a,b** respectively.



The new catalysts were tested first in the borohydride reduction of pivalophenone. This reaction is known to give sizeable, though not spectacular enantiomeric excesses with known catalysts QUIBEC, BCDC, and BCNC (abbreviations, see ref.[23]). Under our chosen conditions all catalysts gave high chemical yields close to 100 %, and these e.e. values were realized with the cinchona alkaloid derived catalysts (major stereoisomer): QUIBEC 30.0 (R), BCDC 23.6 (R), **9a** 23.8 (R), BCNC 18.1 (S), **10a** 18.7 (S), **10b**, 13.6 (S). Our other new catalysts behaved disappointingly. All e.e.s were very low. But at least a certain effect of the structure of substituent R is present, the highest being 4.8 (S) with **4b** carrying a p-bromobenzyl (other p-X-benzyls did much worse) and 5.5 (S) with **8i** having a 9-anthracenylmethyl group.

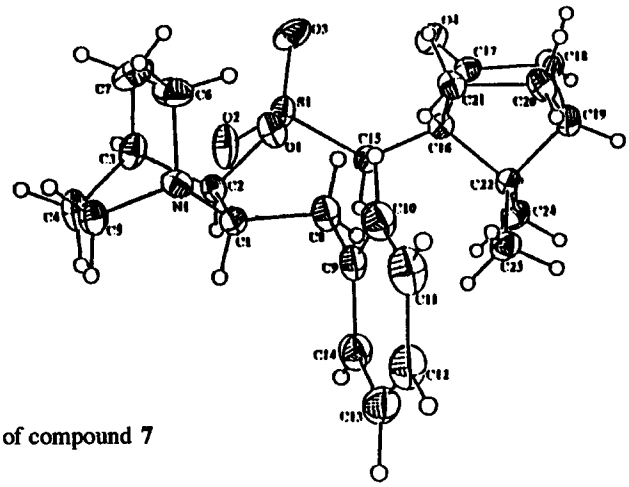
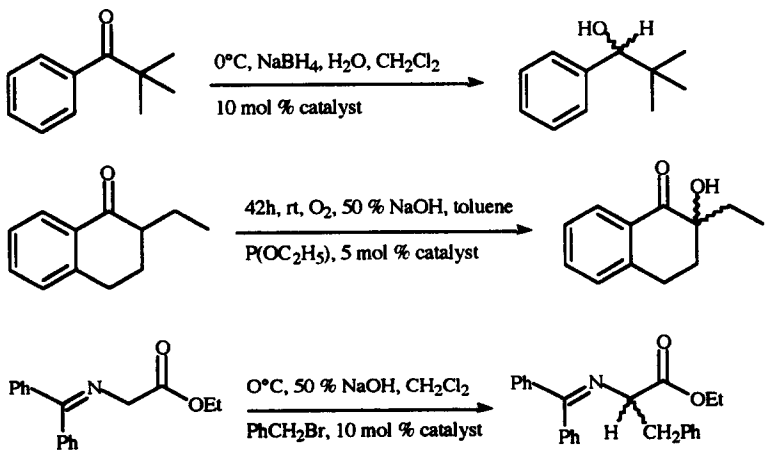


Figure 1: ORTEP View of compound **7**

A second test system was the well studied hydroxylation of 2-ethyl-1-tetralone. Here the chemical yields were variable, depending apparently strongly on the solubility of the catalysts. BCDC and **9a** gave e.e.s of 29.0 (R) and 31.5 (R), whereas BCNC and **10a** yielded 43.3 (S) and 54.4 (S) under our conditions. Interestingly, a change of the p-bromobenzyl to the 9-anthracenylmethyl residue (**10b**) decreased the e.e.to only 4.3 (S). This indicates that large steric requirements in the catalyst are helpful only to a certain point. Beyond that, repulsion makes the ion pairs less intimate resulting in smaller stereoselectivity. The other new catalysts gave much lower e.e.s again, the best being **3c**, **3d**, and **3f** with 4.0, 7.7, and 4.1 (all R), respectively.



The third test reaction was the asymmetric benzylation of ethyl N-diphenylmethylene-glycinate. We find the ethyl ester to give better selectivities than some of the other esters under the conditions used by us. Take notice that none of the results were optimized for e.e., the reactions were run solely to compair different catalysts. Not unexpectedly, **9b** was by far the best catalyst (*cf.*, reff.[8,9]) giving 74.6 % e.e. (S). Other cinchona alkaloid derivatives gave these values: Quibec 15.6, BCDC 51.1 (both S), BCNC 33.6, **10a** 30.7, **10b** 8.3 (all R). In this reaction some of our analogues were able to compete with some of the natural product derived catalysts. The best performers were in the (S) selective series **3a** giving an e.e. of 12.5, **3g** 22.5, **3i** 18.0, **3j** 18.3, and **5** 11.4. **3b-e** furnished e.e.s of 8-10. In the (R) selective series the better results were obtained with **4b-e** (7.6-9.4), **4i** and **4j** (11.7 and 13.3), **8c** (6.8), **8d** (9.6), and **8g** (6.6).

Summary: Thus, it is quite apparent, that a removal of the quinoline carrying arm of the catalysts is not useful although a certain enantioselectivity remains. The N-anthracenylmethyl group introduced by Lygo [8] and Corey [9] is good for an increase in selectivity oftentimes, although a 1-naphthylmethyl is almost as effectful. **5** with a naphthyl residue in the general area of the normal quinoline moiety did perform similarly to **3b** without it. A structural and substitutional change in the quinuclidine core is without merit in two of the three test systems, whereas small enantioselectivities are observed in the alkylation.

Experimental

General Procedures: Melting points were determined using a Büchi 510 melting point apparatus and are uncorrected.- ^{1}H NMR and ^{13}C NMR spectra were recorded on a Brucker AC 250-P spectrometer operating at 250 MHz for ^{1}H and at 62 MHz for ^{13}C. Chemical shifts are in ppm relative to TMS as internal standard. Infrared spectra were recorded on a Mattson Model Genesis FT-IR. Optical rotations (in degrees) were measured with a Jasco Model DIP-360 polarimeter. Elemental analyses were preformed on a Leco Model CHNS-932. GC analyses were performed on a Carlo Erba Fractovap 4200 with a capillary column (OV 17.100 3%, 80/100 mesh, 3 m). HPLC analyses were performed on a LDC Constrametic Model I and Model III pump using a chiral column (Merck Chirasep DNBPG) and a Thermo Separation Products Spectra System UV 100 detector at 254 nm. TLC was performed on Merck silicagel F_{254} plates (0.20 mm) precoated with fluorescent indicator. Visualizion was effected with UV-light or with $KMnO_4$ (0.5% w/v) in water. Flash column chromatography was carried out on E. Merck silicagel 60 (70-230 mesh) using the solvents listed under individual experiments.

General Method for the preparation of the PT-catalysts 3a-i, 4a-i, 8a-i: A solution of the quinuclidine (1.20 mmol) and the necessary halide (1.26 mmol) was stirred in dry acetonitrile at rt or under boiling (compounds **8**) until the amine had been consumed (4-23 h). The reaction was monitored by TLC (ethyl acetate / triethylamine 100:1). The solvent was removed under reduced pressure and the residue was stirred with diethyl ether (7.0 mL) or ethyl acetate for 0.5-72 h. The PT-catalyst was filtered off and sometimes recrystallized from chloroform. The crystals were washed with diethyl ether or ethyl acetate, then dried *in vacuo*.

(2S,5R)-N-Benzyl-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**3a**). Yield 86%; mp 162°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.63-2.16 (m, 5 H), 2.65-2.71 (m, 1 H), 3.15-4.03 (m, 7 H), 4.59 (d, J = 12.9 Hz, 1 H), 4.69 (d, J = 12.9 Hz, 1 H), 5.13-5.23 (m, 2 H), 5.68 (t, J = 5.1 Hz, 1 H), 5.89 (ddd, J = 17.3; 10.3 and 7.0 Hz, 1 H), 7.49-7.63 (m, 5 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.66, 24.10, 26.08, 37.00, 49.94, 58.70, 60.17, 63.58, 65.64, 116.72, 127.84, 128.79, 129.91, 133.24, 137.81.- IR (KBr) 3274 (s), 3054 (w), 2992 (m), 2946 (m), 2896 (m), 1643 (w), 1454 (m), 1056 (s) cm^{-1}.- Analysis for $C_{17}H_{24}BrNO$ requires C 60.36, H 7.15, N 4.14, found C 60.36, H 6.91, N 4.01.- $[\alpha]^{27}_D$-14.2 (c 0.35, MeOH).

(2S,5R)-N-(p-Bromobenzyl)-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**3b**). Yield 87%; mp 208-209°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.61-2.15 (m, 5 H), 2.64-2.77 (m, 1 H), 3.15-4.07 (m, 7 H), 4.59 (d, J = 12.9 Hz, 1 H), 4.69 (d, J = 12.9 Hz, 1 H), 5.13-5.24 (m, 2 H), 5.68 (t, J = 5.0 Hz,

1 H), 5.88 (ddd, J = 17.2, 10.3 and 7.0 Hz, 1 H), 7.58 (d, J = 8.5 Hz, 2 H), 7.71 (d, J = 8.4 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.66, 24.11, 26.08, 37.06, 49.90, 58.61, 60.23, 62.70, 65.61, 116.74, 123.81, 127.22, 131.75, 135.33, 137.76.- IR (KBr) 3301 (s), 3019 (w), 2981 (m), 2935 (m), 2877 (m), 1639 (w), 1457 (m), 1072 (s) cm^{-1}.- Analysis for $C_{17}H_{23}Br_2NO$ requires C 48.94, H 5.56, N 3.36, found C 48.86, H 5.49, N 3.25.- $[\alpha]^{27}_D$-6.8 (c 0.55, MeOH).

(2S,5R)-2-Hydroxymethyl-N-(p-iodobenzyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**3c**). Yield 87%; mp 205 °C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.60-2.14 (m, 5 H), 2.65-2.75 (m, 1 H), 3.16-4.04 (m, 7 H), 4.56 (d, J = 12.9 Hz, 1 H), 4.65 (d, J = 12.9 Hz, 1 H), 5.12-5.24 (m, 2 H), 5.67 (t, J = 5.0 Hz, 1 H), 5.88 (ddd, J = 17.2, 10.3 and 7.0 Hz, 1 H), 7.41 (d, J = 8.3 Hz, 2 H), 7.82 (d, J = 8.4 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.65, 24.10, 26.07, 37.04, 49.89, 58.61, 60.20, 62.90, 65.62, 97.53, 116.73, 127.47, 135.26, 137.60, 137.76.- IR (KBr) 3282 (s), 3077 (w), 2992 (m), 2946 (m), 2873 (m), 1639 (w), 1457 (m), 1068 (s) cm^{-1}.- Analysis for $C_{17}H_{23}BrINO$ requires C 43.99, H 4.99, N 3.02, found C 43.93, H 4.78, N 2.94.- $[\alpha]^{28}_D$- 7.6 (c 0.95, MeOH).

(2S,5R)-2-Hydroxymethyl-N-(p-nitrobenzyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**3d**). Yield 87%; mp 188 °C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.61-2.15 (m, 5 H), 2.68-2.72 (m, 1 H), 3.22-4.08 (m, 7 H), 4.76 (d, J = 12.8 Hz, 1 H), 4.86 (d, J = 12.8 Hz, 1 H), 5.13-5.25 (m, 2 H), 5.73 (t, J = 5.0 Hz, 1 H), 5.88 (ddd, J = 17.2, 10.3 and 7.0 Hz, 1 H), 7.94 (d, J = 8.8 Hz, 2 H), 8.34 (d, J = 8.7 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.68, 24.13, 25.98, 37.09, 50.20, 58.81, 60.29, 62.23, 65.94, 116.81, 123.55, 134.84, 135.11, 137.65, 148.36.- IR (KBr) 3208 (s), 3089 (w), 2992 (w), 2946 (w), 2861 (w), 1639 (w), 1523 (s), 1457 (m), 1349 (s) cm^{-1}.- Analysis for $C_{17}H_{23}BrN_2O_3$ requires C 53.27, 6.05, N 7.31, found C 53.33, H 6.04, N 7.33.- $[\alpha]^{28}_D$- 8.6 (c 0.60, MeOH).

(2S,5R)-2-Hydroxymethyl-N-(p-trifluoromethylbenzyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**3e**). Yield 86%; mp 177-178 °C; ^{1}H NMR (250 MHz, DMSO-d6) δ 1.62-2.16 (m, 5 H), 2.70-2.73 (m, 1 H), 3.22-4.07 (m, 7 H), 4.71 (d, J = 12.9 Hz, 1 H), 4.81 (d, J = 12.9 Hz, 1 H), 5.13-5.25 (m, 2 H), 5.72 (t, J = 5.0 Hz, 1 H), 5.89 (ddd, J = 17.2, 10.3 and 7.0 Hz, 1 H), 7.88 (s, 4 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.70, 24.11, 26.03, 37.06, 50.08, 58.76, 60.25, 62.60, 65.91, 116.76, 123.90 (q, ^{1}J = 272.6 Hz), 125.57 (q, ^{3}J = 3.8 Hz), 130.14 (q, ^{2}J = 32.1 Hz), 132.50, 134.23, 137.74.- IR (KBr) 3282 (s), 3023 (w), 2981 (m), 2946 (m), 2881 (m), 1643 (w), 1461 (m), 1326 (s), 1164 (s), 1126 (s), 1068 (s) cm^{-1}.- Analysis for $C_{18}H_{23}BrF_3NO$ requires C 53.21, H 5.71, N 3.45, found C 53.06, H 5.48, N 3.34.- $[\alpha]^{27}_D$-6.4 (c 0.67, MeOH).

(2S,5R)-N-Cinnamyl-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**3f**). Yield 85%; mp 179-180 °C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.61-2.14 (m, 5 H), 2.80-2.83 (m, 1 H), 3.27-3.84 (m, 7 H), 4.09 (dd, J = 13.3 and 7.6 Hz, 1 H), 4.29 (dd, J = 13.3 and 7.2 Hz, 1 H), 5.14-5.26 (m, 2 H), 5.57 (t, J = 5.2 Hz, 1 H), 5.95 (ddd, J = 17.2, 10.3 and 7.0 Hz, 1 H), 6.43-6.56 (m, 1 H), 6.91 (d, J = 15.7 Hz, 1 H), 7.31-7.44 (m, 3 H), 7.56-7.60 (m, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.34, 24.38, 26.15, 37.32, 50.84, 59.63, 60.04, 62.81, 64.27, 116.75, 116.79, 127.04, 128.55, 128.70, 135.33, 137.93, 140.02.- IR (KBr) 3274 (s), 3066 (w), 2996 (m), 2935 (m), 2877 (m), 1639 (w), 1450 (m), 1056 (s) cm^{-1}.- Analysis for $C_{19}H_{26}BrNO$ requires C 62.64, H 7.19, N 3.84, found C 62.40, H 6.90, N 3.85.- $[\alpha]^{28}_D$ +16.4 (c 0.95, MeOH).

(2S,5R)-2-Hydroxymethyl-N-(1-naphthylmethyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane chloride (**3g**). Yield 85%; mp 210-212°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.73-2.14 (m, 5 H), 2.61-2.65 (m, 1 H), 3.17-4.09 (m, 7 H), 4.88-5.38 (m, 4 H), 5.89 (ddd, J = 17.2, 10.3 and 7.0, 1 H), 6.08-6.16 (m, 1 H), 7.59-7.75 (m, 3 H), 7.91-8.51 (m, 4 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.92, 24.18, 25.68, 37.03, 49.62, 58.65, 60.04, 60.17, 67.03, 116.63, 124.02, 124.07, 125.22, 126.11, 127.27, 128.96, 131.03, 133.02, 133.58, 133.96, 137.87.- IR (KBr) 3822-3054 (s), 2992 (m), 2946 (m), 2885 (m), 1639 (w), 1461 (m), 1064 (s) cm^{-1}.- Analysis for $C_{21}H_{26}ClNO$ requires C 73.35, H 7.62, N 4.07, found C 73.12, H 7.69, N 3.85.- $[\alpha]^{27}_D$ -52.1 (c 0.45, MeOH). (H- and C-NMR seem to indicate that two conformers of **3g** are present in solution).

(2S,5R)-2-Hydroxymethyl-N-(2-naphthylmethyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**3h**). Yield 78%; mp 213°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.66-2.17 (m, 5 H), 2.68-2.72 (m, 1 H), 3.26-4.09 (m, 7 H), 4.79 (d, J = 12.9 Hz, 1 H), 4.87 (d, J = 12.9 Hz, 1 H), 5.12-5.24 (m, 2 H), 5.74 (t, J = 5.1 Hz, 1 H), 5.89 (ddd, J = 17.2, 10.3 and 7.1 Hz, 1 H), 7.58-8.05 (m, 6 H), 8.21 (s, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.69, 24.15, 26.14, 37.11, 49.94, 58.77, 60.22, 63.66, 65.70, 116.74, 125.36,

126.64, 127.34, 127.51, 128.22, 129.75, 132.45, 133.15, 133.45, 137.85.- IR (KBr) 3245 (s), 3087 (w), 2975 (m), 2950 (m), 2863 (m), 1637 (w), 1450 (m), 1110 (m), 1056 (s) cm^{-1}.- Analysis for $C_{21}H_{26}BrNO$ requires C 64.95, H 6.75, N 3.61, found C 64.75, H 6.89, N 3.70.- $[\alpha]^{28}_D$ -21.0 (c 0.45, MeOH).

(2S,5R)-N-(9-Anthracenylmethyl)-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane chloride (**3i**). Yield 83%; pale yellow solid; mp 185°C (decomp.).- ^1H NMR (250 MHz, DMSO-d6) δ 1.54-2.23 (m, 5 H), 2.41-4.38 (m, 8 H), 5.06-5.15 (m, 2 H), 5.62 (d, J = 14.5 Hz, 1 H), 5.89 (ddd, J = 17.1, 10.4 and 6.9 Hz, 1 H), 6.10 (d, J = 14.4 Hz, 1 H), 6.32 (t, J = 5.0 Hz, 1 H), 7.59-7.75 (m, 4 H), 8.23 (d, J = 7.9 Hz, 2 H), 8.56 (d, J = 8.9 Hz, 1 H), 8.79 (d, J = 9.0 Hz, 1 H), 8.91 (s, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 24.04, 24.33, 25.13, 37.12, 49.93, 55.92, 59.02, 60.61, 67.65, 116.56, 119.19, 124.52, 124.83, 125.29, 127.45, 127.57, 129.43, 130.94, 131.00, 131.64, 132.70, 132.96, 137.95.- IR (KBr) 3390 (w), 3193 (s), 3054 (m), 2939 (m), 2877 (w), 1623 (w), 1454 (m), 1052 (m) cm^{-1}.- Analysis for $C_{25}H_{28}ClNO$ requires C 76.22, H 7.16, N 3.56, found C 76.09, H 7.33, N 3.69.- $[\alpha]^{28}_D$ -53.0 (c 0.48, MeOH). (The C NMR indicates that rotation of the anthracenyl residue is restricted).

(2R,5R)-N-Benzyl-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**4a**). Yield 93%; mp 241°C (decomp.).- ^1H NMR (250 MHz, DMSO-d6) δ 1.86-1.99 (m, 5 H), 2.59-2.69 (m, 1 H), 2.84-3.74 (m, 5 H), 3.89 (dd, J = 13.5 and 4.3 Hz, 1 H), 4.07 (dd, J = 13.5 and 2.8 Hz, 1 H), 4.49 (d, J = 12.8 Hz, 1 H), 4.60 (d, J = 12.8 Hz, 1 H), 5.14-5.21 (m, 2 H), 5.65 (s, 1 H), 5.89 (ddd, J = 17.6, 10.4 and 6.9 Hz, 1 H), 7.48-7.62 (m, 5 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.39, 23.55, 26.10, 36.54, 52.65, 54.80, 58.86, 62.73, 67.03, 116.73, 127.85, 128.79, 129.87, 133.30, 137.03.- IR (KBr) 3243 (s), 3077 (w), 2973 (m), 2942 (m), 2877 (m), 1643 (w), 1454 (m), 1100 (m) cm^{-1}.- Analysis for $C_{17}H_{24}BrNO$ requires C 60.36, H 7.15, N 4.14, found C 60.16, H 7.01, N 4.10.- $[\alpha]^{28}_D$ +59.4 (c 0.34, MeOH).

(2R,5R)-N-(p-Bromobenzyl)-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**4b**). Yield 92%; mp 196-197°C.- ^1H NMR (250 MHz, DMSO-d6) δ 1.85-1.99 (m, 5 H), 2.65-2.68 (m, 1 H), 2.88-4.61 (m, 7 H), 4.49 (d, J = 12.8 Hz, 1 H), 4.59 (d, J = 12.8 Hz, 1 H), 5.13-5.19 (m, 2 H), 5.62 (t, J = 4.9 Hz, 1 H), 5.88 (ddd, J = 17.6, 10.3 and 6.9 Hz, 1 H), 7.56 (d, J = 8.4 Hz, 2 H), 7.72 (d, J = 8.4 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.40, 23.55, 26.07, 36.57, 52.57, 54.69, 58.87, 61.87, 67.20, 116.73, 123.78, 127.25, 131.75, 135.39, 137.02.- IR (KBr) 3239 (s), 2981 (m), 2939 (m), 2861 (m), 1639 (w), 1488 (m), 1450 (m), 1114 (m) cm^{-1}.- Analysis for $C_{17}H_{23}Br_2NO$ requires C 48.94, H 5.56, N 3.36, found C 48.72, H 5.60, N 3.34.- $[\alpha]^{27}_D$ +41.9 (c 0.56, MeOH).

(2R,5R)-2-Hydroxymethyl-N-(p-iodobenzyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**4c**). Yield 87%; mp 228-230 °C; ^1H NMR (250 MHz, DMSO-d6) δ 1.84-1.96 (m, 5 H), 2.62-2.65 (m, 1 H), 2.87-4.05 (m, 7 H), 4.44 (d, J = 12.8 Hz, 1 H), 4.55 (d, J = 12.8 Hz, 1 H), 5.12-5.19 (m, 2 H), 5.67 (s, 1 H), 5.87 (ddd, J = 17.9, 10.2 and 7.0 Hz, 1 H), 7.39 (d, J = 8.3 Hz, 2 H), 7.88 (d, J = 8.2 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.40, 23.56, 26.06, 36.56, 52.57, 54.72, 58.88, 62.13, 67.20, 97.47, 116.72, 127.49, 135.32, 137.01, 137.61.- IR (KBr) 3255 (s), 3073 (w), 2985 (m), 2939 (m), 2881 (m), 1639 (w), 1450 (m), 1114 (m) cm^{-1}.- Analysis for $C_{17}H_{23}BrINO$ requires C 43.99, H 4.99, N 3.02, found C 43.85, H 4.84, N 2.95.- $[\alpha]^{28}_D$+30.5 (c 0.43, MeOH).

(2R,5R)-2-Hydroxymethyl-N-(p-nitrobenzyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**4d**). Yield 90%; mp 190-191°C.- ^1H NMR (250 MHz, DMSO-d6) δ 1.90-1.98 (m, 5 H), 2.60-2.63 (m, 1 H), 2.91-4.09 (m, 7 H), 4.67 (d, J = 12.7 Hz, 1 H), 4.78 (d, J = 12.7 Hz, 1 H), 5.13-5.20 (m, 2 H), 5.67 (s, 1 H), 5.89 (ddd, J = 17.8, 10.2 and 7.0 Hz, 1 H), 7.93 (d, J = 8.7 Hz, 2 H), 8.34 (d, J = 8.7 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.44, 23.56, 26.02, 36.68, 52.88, 54.92, 58.89, 61.40, 67.55, 116.79, 123.55, 134.90, 135.20, 136.95, 148.36.- IR (KBr) 3235 (m), 2981 (w), 2950 (w), 2877 (w), 1639 (w), 1523 (s), 1461 (m), 1346 (s) cm^{-1}.- Analysis for $C_{17}H_{23}BrN_2O_3$ requires C 53.27, H 6.05, N 7.31, found C 53.02, H 5.96, N 7.19.- $[\alpha]^{28}_D$ +47.1 (c 0.49, MeOH).

(2R,5R)-2-Hydroxymethyl-N-(p-trifluoromethylbenzyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**4e**). Yield 76%; mp 185-187°C.-^1H NMR (250 MHz, DMSO-d6) δ 1.86-1.98 (m, 5 H), 2.63-2.66 (m, 1 H), 2.89-4.08 (m, 7 H), 4.60 (d, J = 12.8 Hz, 1 H), 4.71 (d, J = 12.7 Hz, 1 H), 5.13-5.20 (m, 2 H), 5.66 (s, 1 H), 5.89 (ddd, J = 17.8, 10.2+ 7.0 Hz, 1 H), 7.83-7.91 (m, 4 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.41, 23.58, 26.04, 36.58, 52.81, 54.89, 58.91, 61.82, 67.44, 116.75, 124.06 (q, ^1J = 275.2 Hz), 125.61 (q, ^3J = 3.8 Hz), 130.20 (q, ^2J = 24.7 Hz), 132.55, 134.28, 137.01.-IR (KBr) 3232 (s), 3073 (w), 2985 (m), 2950 (m), 2908(m), 1639(w), 1469 (w), 1322 (s), 1160 (s), 1126 (s), 1068 (s) cm^{-1}.- Analysis for $C_{18}H_{23}BrF_3NO$

requires C 53.21, H 5.71, N 3.45, found C 53.21, H 5.75, N 3.36.-$[\alpha]^{28}_D$ +51.3 (c 0.50,MeOH).
(2R,5R)-N-Cinnamyl-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**4f**). Yield 83%; mp 167-168°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.92-2.07 (m, 5 H), 2.75-2.82 (m, 1 H), 3.30-4.08 (m, 8 H), 4.20 (dd, J = 13.4 and 6.8 Hz, 1 H), 5.16-5.23 (m, 2 H), 5.58 (t, J = 5.0 Hz, 1 H), 5.92 (ddd, J = 17.5, 10.3 and 7.0 Hz, 1 H), 6.45-6.57 (m, 1 H), 6.91 (d, J = 15.7 Hz, 1 H), 7.31-7.44 (m, 3 H), 7.58 (d, J = 6.6 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.14, 23.62, 26.23, 37.16, 54.62, 55.03, 58.81, 61.88, 64.84, 116.78, 117.07, 127.01, 128.56, 128.69, 135.32, 137.02, 139.95.- IR (KBr) 3282 (s), 3081 (w), 2996 (m), 2950 (m), 2877 (m), 1639 (w), 1457 (m), 1056 (s) cm^{-1}.- Analysis for $C_{19}H_{26}BrNO$ requires C 62.64, H 7.19, N 3.84, found C 62.50, H 7.50, N 3.84.- $[\alpha]^{29}_D$ +63.5 (c 0.37, MeOH).
(2R,5R)-2-Hydroxymethyl-N-(1-naphthylmethyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane chloride (**4g**). Yield 87%; mp 235°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.78-2.16 (m, 5 H), 2.49-2.58 (m, 1 H), 2.79-4.33 (m, 7 H), 5.04-5.21 (m, 4 H), 5.90 (ddd, J = 16.9, 10.5 and 6.8 Hz, 1 H), 6.12 (t, J = 4.9 Hz, 1 H), 7.59-7.72 (m, 3 H), 7.89 (d, J = 6.6 Hz, 1 H), 8.06 (d, J = 7.8 Hz, 1 H), 8.13 (d, J = 8.2 Hz, 1 H), 8.42 (d, J = 8.4 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.62, 25.84, 36.84, 53.31, 55.05, 58.98, 67.07, 116.78, 123.92, 123.95, 125.23, 126.12, 127.27, 128.99, 131.04, 132.95, 133.62, 133.98, 137.08.- IR (KBr) 3143 (s), 3077 (m), 2950 (m), 2865 (m), 1639 (w), 1457 (m), 1118 (s) cm^{-1}.- Analysis for $C_{21}H_{26}ClNO$ req. C 73.35, H 7.62, N 4.07, found C 73.31, H 7.52, N 4.29.-$[\alpha]^{29}_D$+72.0 (c 0.51, MeOH).
(2R,5R)-2-Hydroxymethyl-N-(2-naphthylmethyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**4h**). Yield 89%; mp 199-200°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.87-1.97 (m, 5 H), 2.60-2.63 (m, 1 H), 2.93-4.13 (m, 7 H), 4.67 (d, J = 12.8 Hz, 1 H), 4.78 (d, J = 12.8 Hz, 1 H), 5.14-5.20 (m, 2 H), 5.68 (t, J = 4.7 Hz, 1 H), 5.90 (ddd, J = 17.7, 10.2 and 7.1 Hz, 1 H), 7.58-7.71 (m, 3 H), 7.99-8.06 (m, 3 H), 8.20 (s, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.46, 23.57, 26.14, 36.63, 52.73, 54.92, 58.94, 62.87, 67.07, 116.76, 125.36, 126.65, 127.35, 127.50, 128.22, 129.79, 132.46, 133.13, 133.52, 137.07.- IR (KBr) 3262 (s), 3019 (w), 2964 (m), 2950 (m), 2877 (m), 1650 (w), 1461 (m), 1380 (m), 1110 (m) cm^{-1}.- Analysis for $C_{21}H_{26}BrNO$ req.C 64.95, H 6.75, N 3.61, found C 64.89, H 6.50, N 3.47.- $[\alpha]^{29}_D$+43.6 (c 0.45, MeOH).
(2R,5R)-N-(9-Anthracenylmethyl)-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane chloride (**4i**). Yield 91%; pale yellow solid, mp 218°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.62-2.34 (m, 6 H), 2.50-4.61 (m, 7 H), 4.97-5.11 (m, 2 H), 5.71 (d, J = 14.4 Hz, 1 H), 5.74 (d, J = 14.4 Hz, 1 H), 5.87 (ddd, J = 17.3, 10.4 and 7.0 Hz, 1 H), 6.33 (t, J = 4.8 Hz, 1 H), 7.58-7.76 (m, 4 H), 8.23 (d, J = 8.1 Hz, 2 H), 8.51 (d, J = 9.0 Hz, 1 H), 8.78 (d, J = 8.9 Hz, 1 H), 8.91 (s, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.71, 23.90, 25.42, 36.70, 38.69, 54.32, 55.28, 59.37, 66.94, 116.75, 119.03, 124.29, 124.90, 125.31, 127.40, 127.53, 129.39, 129.52, 130.99, 131.64, 132.79, 137.55.- IR (KBr) 3131 (s), 3016 (m), 2927 (m), 2873 (w), 1623 (w), 1446 (m), 1002 (m) cm^{-1}.- Analysis for $C_{25}H_{28}ClNO$ requires C 76.22, H 7.16, N 3.56, found C 76.18, H 7.08, N 3.62.- $[\alpha]^{29}_D$ +12.8 (c 0.48, MeOH). (The C NMR indicates that rotation of the anthracenyl residue is restricted).

Preparation of compounds 3j and 4j: 4-Bromomethylquinoline hydrobromide (328 mg, 1.26 mmol) was dissolved in water (6.1 mL). The solution was treated with 2N NaOH (1.2 mL) and then extracted with dichloromethane (2 x 4.1 mL). The combined organic layers were dried over Na_2SO_4. This solution of 4-bromomethylquinoline was added to a solution of the corresponding quinuclidine **1** or **2** (200 mg, 1.20 mmol) in dry acetonitrile (2.0 mL), and the reaction mixture was stirred for 21 h at rt. The reaction was monitored by TLC (ethyl acetate / triethylamine 100:1). The solvent was removed under reduced pressure and the residue was stirred with diethyl ether (7.0 mL) for 5 h. The PT-catalyst was filtered off and washed with diethyl ether (7.0 mL), then dried *in vacuo*.
(2S,5R)-N-(4-Quinolinylmethyl)-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**3j**). Yield 87%; mp 160°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.72-2.15 (m, 5 H), 2.66-2.77 (m, 1 H), 3.58-4.09 (m, 7 H), 4.86 (d, J = 13.3 Hz, 1 H), 4.96 (d, J = 13.4 Hz, 1 H), 5.14-5.26 (m, 2 H), 5.66 (s, 1 H), 5.93 (ddd, J = 17.2, 10.3 and 7.0 Hz, 1 H), 7.69-7.75 (m, 1 H), 7.81-7.90 (m, 2 H), 8.09 (d, J = 8.4 Hz, 2 H), 8.54 (d, J = 8.4 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.36, 24.40, 25.99, 37.28, 51.59, 59.70, 59.89, 64.23, 65.33, 116.62, 124.33, 127.30, 127.66, 127.92, 129.00, 130.27, 137.47, 137.98, 147.00, 150.13.- IR (KBr) 3234 (s), 3050 (w), 2973 (m), 2946 (m), 2858 (m), 1639 (w), 1592 (m), 1505 (m), 1454 (m), 1114 (m) cm^{-1}.- Analysis for $C_{20}H_{25}BrN_2O$ requires C 61.70, H 6.47, N 7.20, found C 61.57, H 6.41, N 7.10.- $[\alpha]^{28}_D$-9.7 (c 0.37, MeOH).
(2R,5R)-N-(4-Quinolinylmethyl)-2-hydroxymethyl-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**4j**). Yield 85%; mp 134-135°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.90-2.13 (m, 5 H), 2.66-2.71 (m, 1 H),

3.13-4.25 (m, 7 H), 4.74 (d, J = 13.2 Hz, 1 H), 4.93 (d, J = 13.2 Hz, 1 H), 5.16-5.22 (m, 2 H), 5.67 (s, 1 H), 5.93 (ddd, J = 17.7, 10.2 and 7.1 Hz, 1 H), 7.69-7.75 (m, 1 H), 7.79-7.89 (m, 2 H), 8.07-8.13 (m, 2 H), 8.55 (d, J = 8.4 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 23.16, 23.58, 26.17, 36.91, 54.93, 55.47, 58.93, 63.33, 66.22, 116.83, 124.41, 127.29, 127.68, 127.91, 129.05, 130.28, 136.94, 137.48, 147.02, 150.21.- IR (KBr) 3197 (s), 3054 (w), 2958 (m), 2939 (m), 2881 (m), 1639 (w), 1592 (m), 1504 (m), 1461 (m), 1130 (m) cm^{-1}.- Analysis for $C_{20}H_{25}BrN_2O$ requires C 61.70, H 6.47, N 7.20, found C 61.57, H 6.71, N 7.11.- $[\alpha]^{28}_D$ +87.3 (c 0.47, MeOH).

(2S,3R)-N-(p-Bromobenzyl)-2-(1-naphthylmethyloxymethyl)-5-vinyl-1-azoniumbicyclo[2.2.2]octane bromide (**5**). A solution of **1** (500 mg, 2.99 mmol) in dry THF (12 mL) was dropped to NaH (72 mg, 3.0 mmol) at rt. The suspension was stirred for 10 min. Then a solution of 1-chloromethylnaphthalene (530 mg, 3.0 mmol) in dry THF (12 mL) was added. The mixture was heated under reflux for 3 h and stirred at rt for 18 h under argon. The solvent was removed at rt and the residue was treated with water (20 mL) and dichloromethane (20 mL). After separation of the phases the aqueous layer was extracted with dichloromethane (2 x 20 mL) and the combined organic layers were dried over Na_2SO_4. After removal of the solvent, the yellow oil was purified by chromatography (silicagel, ethyl acetate / triethylamine 100:1). The resulting *(2S,3R)-2-(1-naphthylmethyloxymethyl)-5-vinyl-quinuclidine* (330 mg, 1.07 mmol) was added to a solution of p-bromobenzylbromide (293 mg, 1.17 mmol) in dry acetonitrile (3.3 mL) and the reaction mixture was stirred for 21 h at rt. The solvent was removed under reduced pressure and the residue was stirred with diethyl ether (11.6 ml) for 3 h. The PT-catalyst was filtered off and washed with diethyl ether (11.6 ml). It was dried *in vacuo* to give **5** (413 mg, 0.74 mmol, 25%) as a white solid, mp 115-117 °C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.62-2.17 (m, 5 H), 2.70-4.26 (m, 8 H), 4.49 (d, J = 13.0 Hz, 1 H), 4.57 (d, J = 12.7 Hz, 1 H), 5.11-5.23 (m, 4 H), 5.87 (ddd, J = 17.2, 10.3 and 7.0 Hz, 1 H), 7.41-7.72 (m, 8 H), 7.91-7.98 (m, 2 H), 8.19-8.23 (m, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 24.00, 24.28, 25.99, 36.94, 49.58, 58.48, 62.85, 64.25, 68.66, 70.66, 116.79, 123.83, 123.96, 125.28, 125.87, 126.24, 126.90, 126.96, 128.41, 128.64, 131.13, 131.69, 132.92, 133.25, 135.24, 137.68.- IR (KBr) 3034 (w), 2946 (m), 2885 (m), 1639 (w), 1488 (m), 1064 (m), 1103 (m) ,1076 (s) cm^{-1}.- Analysis for $C_{28}H_{31}Br_2NO$ requires C 60.34, H 5.61, N 2.51, found C 59.90, H 5.76, N 2.35.- $[\alpha]^{28}_D$ +0.4 (c 0.53, MeOH).

cis-2-Benzyl-3-hydroxy-quinuclidine (**rac-6**). In a distillation apparatus fitted with a short column and a drying tube filled with $CaCl_2$, 2-benzyl-3-quinuclidone (84.81 g, 394 mmol) and aluminium triisopropylate (245.16 g, 1200 mmol) in dry isopropanol (1200 mL) were heated to 70-75 °C for 6 h in a N_2-stream. A mixture of acetone and isopropanol was distilled off slowly, and isopropanol (1700 mmol) was dropped into the reaction to keep the amount of solvent constant. In the end, the solvents were removed and the residue was treated with water (1300 mL) and 50% aqueous NaOH (1400 mL). The aqueous layer was extracted with dichloromethane (3 x 500 mL), the combined organic layers were over Na_2SO_4, and the solution was concentrated. The formed white solid was filtered off and was recrystallised from acetone : MeOH (1:1, 600 mL). After cooling to -25°C over night the crystalls were filtered off, washed with petroleum ether (500 mL) and dried *in vacuo* to give **rac-6**.A further crop was obtained from the mother liquor. Yield 40.72 g (190 mmol, 48%); mp: 157 °C. (Lit. mp [20] 154- 156°C).

(2R,3R)-2-Benzyl-3-hydroxy-quinuclidinium (S)-pyroglutamate. To a solution of **rac-6** (20.00 g, 92.0 mmol) in acetone : MeOH (10:1, 210mL) was added (S)-pyroglutamic acid (11.88 g, 92.0 mmol). The mixture was heated under reflux for 10 min and then slowly cooled down to -18 °C. The resulting white solid was filtered off and was recrystallised from acetone : MeOH (5:1, 165 mL) repeatedly. Yield: 7.22 g (20.8 mmol, 23%), mp 158-159°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.28-1.67 (m, 3 H), 1.86-2.31 (m, 6 H), 2.68-2.85 (m, 4 H), 3.04-3.13 (m, 2 H), 3.26 (q, J = 7.3 Hz, 1 H), 3.80 (dd, J = 7.5 and 4.4 Hz, 1 H), 3.91 (dd, J = 8.8 and 4.6 Hz, 1 H), 7.12-7.64 (m, 5 H), 8.31 (br s, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 17.84, 22.40, 24.96, 28.31, 29.39, 31.34, 40.64, 47.48, 55.88, 61.76, 65.82, 125.52, 127.84, 129.03, 139.95, 175.09, 176.71.- IR (KBr) 3630-3130 (m), 2995 (m), 2860 (m), 2740 (m), 1710 (s), 1695 (s), 1630 (s), 1435 (s), 1340 (m), 1300 (m) cm^{-1}.-Analysis for $C_{19}H_{26}N_2O_4$ requires C 65.87, H 7.56, N 8.09, found C 65.62, H 7.50, N 8.03.-$[\alpha]^{28}_D$ -42.3 (c 0.93, H_2O).

Optically active (2R,3R)-2-Benzyl-3-hydroxy-quinuclidine (**6**). A solution of **7** (2.21 g, 6.1 mmol) in water (19 mL) was stirred at rt with KOH (0.60 g, 10.7 mmol) and K_2CO_3 (0.70 g, 5.1 mmol) for 5 min. The aqueous layer was extracted with dichloromethane (2 x 50 mL), and the combined organic layers were dried over Na_2SO_4. After the solvent was removed, the residue was sublimated *in vacuo* to give **6** (1.28 g, 5.9 mmol, 92%) as a white solid, mp 171-173 °C.- ^{1}H NMR (250 MHz, $CDCl_3$) δ 1.24-1.99 (m, 6 H), 2.67-2.92 (m, 4 H), 3.11-3.26 (m, 3 H), 3.80 (dd, J = 6.9 and 4.0 Hz, 1 H), 7.15-7.31 (m, 5 H).- IR (KBr) 3536-3000 (s), 2954 (s), 2865 (s), 1600 (w), 1695, 1454 (s), 1346 (m), 1037 (m) cm^{-1}.- Analysis for $C_{14}H_{19}NO$

requires C 77.38, H 8.81, N 6.45, found C 77.33, H 8.71, N 6.36.- $[\alpha]^{28}_D$ -82.6 (c 0.38, $CHCl_3$).

(2R,3R)-2-Benzyl-3-((1S)-10-camphorsulfonyloxymethyl)-quinuclidine (**7**). To a solution of **6** (50 mg, 0.23 mmol) and dry triethylamine (50 mg, 0.49 mmol) in dry chloroform (2.5 mL) was added a solution of (1S)-10-camphorsulfonyl chloride (107 mg, 0.43 mmol) in dry chloroform (0.5 mL) under argon at 0°C. This mixture was stirred at rt for 17 h. After the solvent was removed, the residue was purified by chromatography (silicagel,: ethyl acetate : triethylamine 100:1). Compound **7** (80 mg, 0.19 mmol, 81 %) was obtained as a white solid, mp 128°C (decomp.).- ^{1}H NMR (250 MHz, $CDCl_3$) δ 0.81 (s, 3 H), 1.08 (s, 3 H), 1.36-2.08 (m, 9 H), 2.31-2.49 (m, 3 H), 2.62-3.29 (m, 8 H), 3.37-3.46 (m, 1 H), 4.93-4.98 (m, 1 H), 7.14-7.32 (m, 5 H).-^{13}C NMR (62 MHz, $CDCl_3$) δ 19.08, 19.75, 19.85, 24.21, 25.07, 26.87, 27.98, 33.78, 41.42, 42.51, 42.83, 47.23, 47.92, 48.69, 57.86, 60.19, 81.23, 126.21, 128.48, 128.81, 139.52, 214.14.- IR (KBr) 3023 (w), 2964 (m), 2917 (m), 1741 (s), 1355 (s), 1159 (s), 883 (s) cm^{-1}.- Analysis for $C_{24}H_{33}NO_4S$ requires C 66.79, H 7.71, N 3.25, found C 66.50, H 7.98, N 3.17.- $[\alpha]^{26}_D$ -34.6 (c 0.44, $CHCl_3$). For x-ray structure determination a sample was recrystallized from petroleum ether (b.p. 60-80°C).

X-ray structure determination of 7:

All data were collected at -90 °C on a Siemens Smart CCD diffractometer that was operated in the ω-2θ scan mode using graphite monochromated Mo K_α radiation (λ = 0.71073 Å). Space group assignments were based on systematic absences present in the diffraction pattern and were confirmed by structure solution and refinement. The structure was determined initially by direct methods, aided by the SHELXS-97 computer program, and refined by using the SHELXL-93 full matrix least-squares program.-Data collection and processing parameters for **7**: Formula $C_{24}H_{33}NO_4S$; Size (mm): 0.08 x 0.30 x 0.40; Space group: $P2_1$; a (Å): 9.0787 (6); b : 11.4940 (7); c : 11.0525 (7); α (°): 90.00; ß (°): 106.9320 (10); γ (°): 90.00; V (Å^3): 1103.34 (12); Z-value: 2; D_{calc} (g/cm^3): 1.299; μ (cm^{-1}): 0.177; T (°C): -90 (2); $2\theta_{max}$ (°): 54.0; Total reflections: 4532; Unique reflexions: 4231; parameters: 403; R,R_w: 0.032, 0.029; $(\Delta/\sigma)_{max}$: 0.00; ρ_{max},ρ_{min}(e/Å^3): 0.28, -0.22.-

(2R,3R)-N-Benzyl-2-benzyl-3-hydroxy-1-azoniumbicyclo[2.2.2]octane bromide (**8a**). Yield 60%; mp 90°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.60-2.05 (m, 5 H), 2.88-3.67 (m, 6 H), 3.94-3.97 (m, 1 H), 4.25 (q, J = 6.9 Hz, 1 H), 4.45 (d, J = 12.4 Hz, 1 H), 4.54 (d, J = 12.4 Hz, 1 H), 5.45 (d, J = 4.1 Hz, 1 H), 7.21-7.58 (m, 10 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 17.63, 19.98, 27.28, 27.94, 47.92, 54.47, 62.85, 64.87, 71.33, 126.18, 128.06, 128.12, 128.69, 129.20, 129.83, 133.22, 137.60.- IR (KBr) 3698-3131 (s), 3066 (w), 2973 (m), 2885 (m), 1604 (m), 1496 (s), 1018 (s) cm^{-1}.-Analysis for $C_{21}H_{26}BrNO$ requires C 64.95, H 6.75, N 3.61, found C 65.00, H 6.95, N 3.57.- $[\alpha]^{30}_D$ -67.6 (c 0.25, $CHCl_3$).

(2R,3R)-2-Benzyl-N-(p-bromobenzyl)-3-hydroxy-1-azoniumbicyclo[2.2.2]octane bromide (**8b**). Yield 59%; mp 222°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.60-2.04 (m, 5 H), 2.91-3.60 (m, 6 H), 3.90-4.00 (m, 1 H), 4.20-4.23 (m, 1 H), 4.43 (d, J = 12.4 Hz, 1 H), 4.53 (d, J = 12.4 Hz, 1 H), 5.44 (d, J = 4.2 Hz, 1 H), 7.24 (t, J = 7.2 Hz, 1 H), 7.34 (t, J = 7.3 Hz, 2 H), 7.47-7.52 (m, 4 H), 7.71 (d, J = 8.4 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 17.65, 20.02, 27.28, 27.94, 47.93, 54.42, 61.97, 64.87, 71.51, 123.77, 126.23, 127.48, 128.17, 129.23, 131.71, 135.32, 137.55.- IR (KBr) 3282 (s), 3056 (w), 2981 (m), 2954 (m), 2881 (m), 1592 (m), 1488 (s), 1072 (s) cm^{-1}.- Analysis for $C_{21}H_{25}Br_2NO$ requires C 53.98, H 5.39, N 3.00, found C 53.93, H 5.23, N 2.93.-$[\alpha]^{28}_D$ -64.9 (c 0.43, MeOH).

(2R,3R)-2-Benzyl-N-(p-iodobenzyl)-3-hydroxy-1-azoniumbicyclo[2.2.2]octane bromide (**8c**). Yield 90 % ; mp 250-251°C; ^{1}H NMR (250 MHz, DMSO-d6) δ 1.60-2.03 (m, 5 H), 2.91-3.95 (m, 7 H), 4.18-4.21 (m, 1 H), 4.39 (d, J = 12.4 Hz, 1 H), 4.50 (d, J = 12.4 Hz, 1 H), 5.44 (d, J = 4.1 Hz, 1 H), 7.21-7.26 (m, 1 H), 7.31-7.36 (m, 4 H), 7.48 (d, J = 7.1 Hz, 2 H), 7.87 (d, J = 8.2 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 17.64, 20.01, 27.27, 27.93, 47.93, 54.45, 62.22, 64.86, 71.50, 97.44, 126.23, 127.74, 128.17, 129.23, 135.25, 137.56.- IR (KBr) 3297 (s), 3205 (s), 3052 (w), 2981 (m), 2954 (m), 2881 (m), 1589 (m), 1484 (s), 1457 (s), 1064 (s) cm^{-1}.- Analysis for $C_{21}H_{25}BrINO$ requires C 49.05, H 4.90, N 2.72, found C 49.09, H 5.11, N 2.69.- $[\alpha]^{28}_D$ -67.2 (c 0.50, MeOH).

(2R,3R)-2-Benzyl-3-hydroxy-N-(p-nitrobenzyl)-1-azoniumbicyclo[2.2.2]octane bromide (**8d**). Yield 91%; mp 233-235°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.59-2.07 (m, 5 H), 2.93-3.96 (m, 7 H), 4.25-4.30 (m, 1 H), 4.65 (d, J = 12.3 Hz, 1 H), 4.74 (d, J = 12.3 Hz, 1 H), 5.47 (d, J = 4.1 Hz, 1 H), 7.21-7.53 (m, 5 H), 7.89 (d, J = 8.6 Hz, 2 H), 8.34 (d, J = 8.5 Hz, 2 H).- ^{13}C NMR (62 MHz, DMSO-d6)δ 17.72, 20.06, 27.17, 28.02, 48.27, 54.63, 61.39, 64.87, 71.88, 123.53, 126.27, 128.18, 129.30, 134.82, 135.47, 137.43, 148.35.- IR (KBr) 3230 (s), 3058 (w), 2942 (m), 2929 (m), 2886 (w), 1604 (m), 1525 (s), 1348 (s),

1095 (s) cm^{-1}.- Analysis for $C_{21}H_{25}BrN_2O_3$ requires C 58.21, H 5.81, N 6.46, found C 58.14, H 5.69, N 6.50.- $[\alpha]^{27}_D$ -72.8 (c 0.39, MeOH).

(2R,3R)-2-Benzyl-3-hydroxy-N-(p-trifluoromethylbenzyl)-1-azoniumbicyclo[2.2.2]octane bromide (**8e**). Yield 91%; mp 228-230°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.62-2.06 (m, 5 H), 2.92-3.98 (m, 7 H), 4.35 (q, J = 6.9 Hz, 1 H), 4.67 (d, J = 12.8 Hz, 1 H), 4.72 (d, J = 12.8 Hz, 1 H), 5.55 (d, J = 4.1 Hz, 1 H), 7.24 (t, J = 7.2 Hz, 1 H), 7.34 (d, J = 7.3 Hz, 2 H), 7.55 (d, J = 7.2 Hz, 2 H), 7.87 (s, 4 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 17.75, 20.13, 27.31, 28.14, 48.31, 54.60, 61.73, 64.98, 71.75, 123.98 (q, ^{1}J = 268.7 Hz), 125.58 (q, ^{3}J = 3.7 Hz), 126.30, 128.22, 129.44, 130.18 (q, ^{2}J = 31.2 Hz), 133.00, 134.33, 137.62.- IR (KBr) 3718-3066 (w), 3027 (m), 2958 (m), 2888 (m), 1619 (w), 1457 (m), 1326 (s), 1168 (s), 1130 (s), 1068 (s) cm^{-1}.- Analysis for $C_{22}H_{25}BrF_3NO$ requires C 57.90, H 5.52, N 3.07, found C 57.69, H 5.64, N 3.03.- $[\alpha]^{31}_D$ -66.5 (c 0.50, MeOH).

(2R,3R)-2-Benzyl-N-cinnamyl-3-hydroxy-1-azoniumbicyclo[2.2.2]octane bromide (**8f**). Yield 79%; mp 161-162°C.- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.74-2.11 (m, 5 H), 3.19-4.19 (m, 10 H), 5.45 (d, J = 4.2 Hz, 1 H), 6.47-6.35 (m, 1 H), 6.87 (d, J = 15.7 Hz, 1 H), 7.19-7.55 (m, 10 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 18.09, 20.17, 27.36, 27.65, 49.99, 54.69, 62.05, 64.65, 69.18, 116.90, 126.26, 126.91, 128.15, 128.59, 128.70, 129.22, 135.28, 137.40, 137.72.- IR (KBr) 3259 (s), 3056 (w), 3025 (w), 2944 (m), 2881 (m), 1602 (m), 1496 (s), 1452 (s), 1018 (s) cm^{-1}.- Analysis for $C_{23}H_{28}BrNO$ requires C 66.67, H 6.81, N 3.38, found C 66.61, H 6.81, N 3.38.- $[\alpha]^{27}_D$ -65.5 (c 0.53, MeOH).

(2R,3R)-2-Benzyl-3-hydroxy-N-(1-naphthylmethyl)-1-azoniumbicyclo[2.2.2]octane chloride (**8g**). Yield 65%; mp 217°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.51-2.07 (m, 5 H), 2.76-3.99 (m, 7 H), 4.59-4.68 (m, 1 H), 4.95 (d, J = 13.5 Hz, 1 H), 5.02 (d, J = 13.5 Hz, 1 H), 5.58 (d, J = 4.1 Hz, 1 H), 7.22-7.39 (m, 3 H), 7.53-7.71 (m, 5 H), 7.86 (d, J = 6.4 Hz, 1 H), 8.03-8.07 (m, 1 H), 8.12 (d, J = 8.1 Hz, 1 H), 8.52 (d, J = 4.1 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 17.84, 20.24, 26.91, 28.27, 48.36, 54.49, 59.60, 65.06, 71.91, 124.20, 124.26, 125.12, 126.12, 126.16, 127.22, 128.12, 128.91, 129.39, 131.05, 132.93, 133.60, 133.97, 137.87.- IR (KBr) 3153 (s), 3010 (w), 2931 (m), 2879 (m), 1602 (m), 1459 (s), 1083 (s) cm^{-1}.- Analysis for $C_{25}H_{28}ClNO$ requires C 76.22, H 7.16, N 3.56, found C 76.31, H 7.36, N 3.57.- $[\alpha]^{28}_D$ -82.9 (c 0.48, MeOH).

(2R,3R)-2-Benzyl-3-hydroxy-N-(2-naphthylmethyl)-1-azoniumbicyclo[2.2.2]octane bromide (**8h**). Yield 94%; mp 202°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.60-2.09 (m, 5 H), 3.04-3.70 (m, 6 H), 3.94-4.04 (m, 1 H), 4.27-4.32 (m, 1 H), 4.62 (d, J = 12.5 Hz, 1 H), 4.71 (d, J = 12.5 Hz, 1 H), 5.47 (d, J = 4.2 Hz, 1 H), 7.23-8.10 (m, 11 H), 8.32 (s, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 17.70, 20.11, 27.41, 27.95, 48.13, 54.67, 63.13, 64.91, 71.33, 125.54, 126.25, 126.71, 127.37, 127.52, 128.10, 128.21, 129.23, 129.73, 132.36, 133.11, 133.43, 137.73.- IR (KBr) 3315 (s), 3060 (w), 2944 (s), 2885 (m), 1600 (w), 1454 (m), 1056 (m) cm^{-1}.- Analysis for $C_{25}H_{28}BrNO$ requires C 68.49, H 6.44, N 3.19, found C 68.47, H 6.68, N 3.19.- $[\alpha]^{27}_D$ -56.4 (c 0.20, MeOH).

(2R,3R)-N-(9-Anthracenylmethyl)-2-benzyl-3-hydroxy-1-azoniumbicyclo[2.2.2]octane chloride (**8i**). Yield 70%; pale yellow solid; mp 197°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.33-2.07 (m, 5 H), 2.51-3.93 (m, 7 H), 4.80-4.93 (m, 1 H), 5.48 (d, J = 4.0 Hz, 1 H), 5.51 (d, J = 14.2 Hz, 1 H), 5.61 (d, J = 14.2 Hz, 1 H), 7.27 (t, J = 7.3 Hz, 1 H), 7.38-7.43 (m, 2 H), 7.60-7.76 (m, 6 H), 8.23 (d, J = 8.3 Hz, 2 H), 8.59 (d, J = 8.8 Hz, 1 H), 8.79 (d, J = 8.9 Hz, 1 H), 8.91 (s, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 18.05, 20.35, 26.30, 28.55, 49.26, 54.49, 55.36, 65.13, 71.26, 119.09, 124.78, 124.96, 125.28, 126.17, 127.35, 127.58, 128.10, 129.35, 129.41, 129.49, 130.94, 130.98, 131.68, 132.69, 132.76, 137.86.- IR (KBr) 3162 (s), 3054 (m), 2939 (m), 2888 (w), 1623 (m), 1446 (s), 1087 (m) cm^{-1}.- Analysis for $C_{29}H_{30}ClNO$ requires C 78.45, H 6.81, N 3.15, found C 78.36, H 7.03, N 3.12.- $[\alpha]^{27}_D$ -86.4 (c 0.38, MeOH). (The C NMR indicates that rotation of the anthracenyl residue is restricted).

(2R,3R)-N-(4-Quinolinylmethyl)-2-benzyl-3-hydroxy-1-azoniumbicyclo[2.2.2]octane bromide (**8j**) was prepared similarly to **3j**. Yield: 87%; mp 190°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.72-2.21 (m, 5 H), 3.18-3.94 (m, 7 H), 4.45-4.50 (m, 1 H), 4.81 (d, J = 13.8 Hz, 1 H), 4.96 (d, J = 13.8 Hz, 1 H), 5.41 (d, J = 4.1 Hz, 1 H), 7.17-7.38 (m, 5 H), 7.69-8.10 (m, 5 H), 8.54 (d, J = 8.4 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 18.10, 20.12, 27.39, 28.12, 51.20, 55.11, 63.16, 64.51, 69.93, 123.85, 126.18, 127.22, 127.61, 127.97, 128.02, 128.81, 129.22, 130.34, 137.23, 137.54, 146.89, 150.67.- IR (KBr) 3230 (s), 3052 (w), 2958 (m), 2885 (m), 1617 (w), 1598 (m), 1506 (m), 1064 (m) cm^{-1}.- Analysis for $C_{24}H_{27}BrN_2O$ req.C 65.60, H 6.19, N 6.38,found C 65.60, H 6.10, N 6.11.-$[\alpha]^{28}_D$-107.3 (c 0.47, MeOH).

N-(p-Bromobenzyl)-cinchonidinium bromide (**9a**). Cinchonidine (300 mg, 1.02 mmol) and p-bromobenzyl bromide (270 mg, 1.08 mmol) in dry chloroform (3.5 ml) were stirred at rt for 17 h. The solvent was removed and the residue was stirred with diethyl ether / chloroform (2:1, 12 mL) for 17 h, filtered off and washed with a small amount of this solvent mixture. This procedure was repeated to yield **9a** (359 mg, 0.66 mmol, 65 %) as a pale yellow solid, mp 202 °C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.28-2.24 (m, 5 H), 2.63-2.70 (m, 1 H), 3.22-4.23 (m, 5 H), 4.96-5.00 (m, 2 H), 5.13-5.16 (m, 2 H), 5.67 (ddd, J = 17.3, 10.6 and 6.5 Hz, 1 H), 6.54 (br s, 1 H), 6.77 (d, J = 4.3 Hz, 1 H), 7.69 (d, J = 8.4 Hz, 2 H), 7.74-7.84 (m, 5 H), 8.11 (d, J = 8.3 Hz, 1 H), 8.27 (d, J = 8.4 Hz, 1 H), 8.98 (d, J = 4.5 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 20.95, 24.26, 25.87, 36.92, 50.59, 59.25, 61.93, 64.08, 67.82, 116.38, 120.11, 123.63, 124.06, 124.33, 127.23, 127.37, 129.47, 129.88, 131.95, 135.83, 138.09, 145.28, 147.62, 150.15.- IR (KBr) 3691-3235 (s), 3139 (s), 3039 (m), 2981 (m), 2946 (m), 1616 (w), 1592 (m), 1488 (m), 755 (m) cm^{-1}.- Analysis for $C_{26}H_{28}Br_2N_2O$ req.C 57.37, H 5.18, N 5.15, found C 57.22, H 5.31, N 5.01.-$[\alpha]^{28}_D$-113.2 (c 0.78, MeOH).

N-(9-Anthracenylmethyl)-cinchonidinium bromide (**9b**). Cinchonidine (500 mg, 1.70 mmol) and 9-chloromethylanthracene (580 mg, 2.56 mmol) in dry toluene (15 ml) were heated under reflux for 2 h. The mixture was cooled down to 4 °C overnight, the resulting solid was filtered off and washed with a small amount of toluene. It was dried *in vacuo* to afford **9b** (590 mg, 1.13 mmol, 67 %) as a pale yellow solid, mp 157°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.35-2.49 (m, 6 H), 2.75-3.08 (m, 2 H), 3.80-3.92 (m, 1 H), 4.50-4.65 (m, 2 H), 4.93-5.04 (m, 2 H), 5.70 (ddd, J = 17.3, 10.4 and 7.0 Hz, 1 H), 5.88 (d, J = 13.8 Hz, 1 H), 6.50 (d, J = 14.0 Hz, 1 H), 7.02 (br s, 1 H), 7.52-7.94 (m, 8 H), 8.13-8.17 (m, 1 H), 8.26 (d, J = 8.4 Hz, 2 H), 8.65 (d, J = 7.6 Hz, 1 H), 8.86-8.96 (m, 3 H), 9.03 (d, J = 4.5 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 21.16, 24.56, 25.23, 37.37, 51.27, 55.39, 60.18, 64.44, 68.32, 116.44, 119.10, 120.25, 124.19, 124.55, 125.04, 125.17, 125.31, 125.37, 127.04, 127.43, 127.58, 129.34, 129.42, 129.50, 129.72, 131.00, 131.06, 131.87, 133.00, 133.06, 137.98, 145.78, 147.69, 150.09.- IR (KBr) 3606-3282 (m), 3058 (s), 2954 (m), 2933 (m), 2881 (w), 1623 (m), 1450 (s), 1160 (s), 1133 (m) cm^{-1}.- Analysis for $C_{34}H_{33}ClN_2O$ requires C 78.37, H 6.38, N 5.38, found C 78.13, H 6.21, N 5.30.- $[\alpha]^{27}_D$ -1012.0 (c 0.23, MeOH). (As in previous cases: restricted rotation of the anthracenyl moiety).

N-(p-Bromobenzyl)-cinchoninium bromide (**10a**). Cinchonine (300 mg, 1.02 mmol) and p-bromobenzyl bromide (270 mg, 1.08 mmol) in dry chloroform (12 ml) were heated under reflux for 40 min and then stirred at rt for 19 h. The solvent was removed and the residue was stirred with acetone / MeOH (10:1, 7.0 mL), filtered off and washed with a small amount of acetone. The solid was stirred again with acetone (7.0 mL) for 15 min, then filtered off. It was dried *in vacuo* to afford 429 mg (0.79 mmol, 77%) as a pale yellow solid; mp 224 °C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.05-2.34 (m, 5 H), 2.63-2.66 (m, 1 H), 2.96-4.24 (m, 5 H), 4.92 (d, J = 12.3 Hz, 1 H), 5.10 (d, J = 12.3 Hz, 1 H), 5.18-5.25 (m, 2 H), 5.93-6.07 (m, 1 H), 6.50 (br s, 1 H), 6.78 (d, J = 3.8 Hz, 1 H), 7.70-7.78 (m, 7 H), 8.11 (d, J = 7.4 Hz, 1 H), 8.34 (d, J = 8.1 Hz, 1 H), 8.99 (d, J = 4.5 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 20.52, 22.88, 26.21, 36.55, 53.74, 55.83, 61.41, 64.61, 67.20, 116.88, 119.97, 123.68, 123.94, 124.27, 127.09, 127.17, 129.29, 129.73, 131.85, 135.73, 137.00, 144.82, 147.59, 150.06.- IR (KBr) 3127 (s), 3100 (s), 2989 (m), 2906 (m), 1643 (w), 1589 (m), 1488 (m), 1465 (m) cm^{-1}.- Analysis for $C_{26}H_{28}Br_2N_2O$ requires C 57.37, H 5.18, N 5.15, found C 57.11, H 5.18, N 5.04.- $[\alpha]^{28}_D$ +123.3 (c 0.17, MeOH).

N-Cinnamyl-cinchoninium bromide (**10b**). Prepared similarly to **10a** from cinchonine (300 mg, 1.02 mmol) and cinnamyl bromide (213 mg, 1.08 mmol). Yield of **monohydrate**: 226 mg (0.79 mmol, 77 %), mp 170°C (decomp.).- ^{1}H NMR (250 MHz, DMSO-d6) δ 1.00-2.25 (m, 5 H), 2.79-2.81 (m, 1 H), 3.35-4.71 (m, 8 H), 5.24-5.28 (m, 2 H), 6.00-6.07 (m, 1 H), 6.34 (br s, 1 H), 6.79 (d, J = 3.9 Hz, 1 H), 6.86-6.89 (m, 1 H), 7.18 (d, J = 15.7 Hz, 1 H), 7.33-7.79 (m, 7 H), 8.06 (d, J = 8.4 Hz, 1 H), 8.08 (d, J = 8.4 Hz, 1 H), 8.97 (d, J = 4.6 Hz, 1 H).- ^{13}C NMR (62 MHz, DMSO-d6) δ 20.27, 23.07, 26.21, 37.09, 55.98, 56.07, 61.50, 64.75, 64.89, 116.92, 117.37, 119.94, 123.38, 124.16, 126.79, 127.08, 128.72, 128.90, 129.20, 129.70, 135.29, 136.97, 139.68, 144.96, 147.43, 150.08.- IR (KBr) 3579-3016 (s), 2954 (m), 1635 (w), 1589 (w), 1446 (m), 1122 (s) cm^{-1}.- Analysis for $C_{28}H_{31}BrN_2O \cdot H_2O$ requires C 66.01, H 6.53, N 5.50, found C 66.24, H 6.43, N 5.33; $[\alpha]^{29}_D$ +85.1 (c 0.53, MeOH).

Typical procedure for the asymmetric reduction of pivalophenone under PTC conditions: Pivalophenone (162 mg, 1.00 mmol) and PT-catalyst (0.10 mmol) were dissolved in dichloromethane (3.0 mL) and water (0.5 mL), and the mixture was stirred at 0 °C for 10 min. Then $NaBH_4$ (23 mg) was added and stirring was continued at 0 °C for several hours. The reaction was monitored by TLC (petroleum ether / diethyl ether 4:1). After the consumption of the starting material, dichloromethane (7.0 mL) was added and the organic layer was washed with water (2 x 7.0 mL) and dried over Na_2SO_4 .The solvent was removed to yield 2,2-dimethyl-1-phenyl-1-propanol as a white or pale yellow solid. Enantiomeric excess was determined by

HPLC using Merck Chirasep DNBPG with hexane / i -PrOH (200:1). The retention time was 14.4 min for the (S)-isomer and 15.3 min for the (R)-isomer at a flow rate of 0.5 mL/min.

Typical procedure for the asymmetric oxidation of 2-ethyl-1-tetralone under PTC conditions: A mixture of 50% aqueous NaOH (2.5 mL), toluene (7.5 mL), triethyl phosphite (0.25 mL), 2-ethyl-1-tetralone (174 mg, 1.00 mmol) and PT-catalyst (0.05 mmol) was stirred at rt for 42 h in a micro hydrogenation apparatus fitted with an O_2-balloon . Thereafter toluene (10 mL) and water (20 mL) were added, and the phases were separated. The aqueous layer was extracted with toluene (15 mL), and the combined organic layers were washed with 10% aqueous HCl (10 mL), with water (10 mL) and brine (10 mL). They were dried over Na_2SO_4. The solvent was removed, and the residue was purified by chromatography on silicagel with toluene or petroleum ether / ethyl acetate (10 : 1) to give 2-ethyl-2-hydroxy-1-tetralone as a pale yellow oil. The mass of the product was determined, and relative yields were assayed by GC with a temperature program (4 min: 100 °C, then 5 °C/min up to 180 °C).- Enantiomeric excesses were determined by HPLC using Merck Chirasep DNBPG with eluent hexane / i-PrOH (500:1). With a 0.5 mL/min flow rate the retention time was 62.1 min for the (R)-isomer and 66.1 min for the (S)-isomer.

Typical procedure for the asymmetric benzylation of N-(diphenylmethylen)-glycine ethyl ester under PTC conditions: N-(Diphenylmethylen)-glycine ethyl ester (267 mg, 1.00 mmol), benzyl bromide (171 mg, 1.00 mmol) and PT-catalyst (0.10 mmol) were dissolved in dichloromethane (10 mL) and the mixture was stirred at 0 °C for 10 min. Then 50% aqueous NaOH (2.5 mL) was added and stirring was continued for several hours at 0 °C. The reaction was monitoredby TLC (petroleum ether / tert-butyl methyl ether 5:1). After the consumption of the starting material, dichloromethane (7.0 mL) and water (7.0 mL) were added and the phases were separated. The organic layer was dried over Na_2SO_4, and the solvent was removed. The residue was stirred with petroleum ether / tert-butyl methyl ether 5:1 (20 mL) and was filtered. The filtrate was concentrated to yield benzyl-N-(diphenylmethylen)-glycine ethyl ester as a white or pale yellow solid. Yield was determined by ^1H NMR (byproduct: benzophenone). Enantiomeric excess was determined by HPLC using Merck Chirasep DNBPG with eluent hexane / i-PrOH (500:1). With a 0.5 mL/min flow rate the retention time was 37.3 min for the (R)-isomer and 39.5 min for the (S)-isomer.

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References

1. Applications of Phase Transfer Catalysis, Part 69.-For part 68, see: E.V. Dehmlow, R. Klauck, B. Neumann, H.G. Stammler, J. Prakt. Chem. **1998**, *340*, 572.
2. T. Shioiri, "Chiral Phase Transfer Catalysis" in Handbook of Phase Transfer Catalysis, Y. Sasson and R. Neumann, edits., Blackie Academ. & Professional, London, 1997, pp. 462-479.
3. M. J. O'Donnell, "Asymmetric Phase Transfer Reactions" in Catalytic Asymmetric Synthesis, I. Ojima, edit., VCH-Publ., New York, Weinheim, 1993, pp.389-411.
4. E.V. and S.S. Dehmlow, "Phase Transfer Catalysis", 3rd rev., enl. edit., VCH-Publ., Weinheim, New York, 1993, pp. 80-90.
5. D. L. Hughes, U.-H. Dolling, K. M. Ryan, E. F. Schoenewaldt, E. J. J. Grabowski, J. Org. Chem. **1987**,*52*, 4745 and previous publications.
6. T. B. K. Lee, G. S. K. Wong, J. Org. Chem. **1991**, *56*, 872.
7. M. J. O'Donnell, Z. Fang, X. Ma, J. C. Huffman, Heterocycles **1997**,*46*, 617 and previous publications
8. B. Lygo, P. G. Wainwright, Tetrahedron Lett. **1997**, *38*, 8595.
9. E. J. Corey, F. Xu, M. C. Noe, J. Amer. Chem. Soc. **1997**, *119*, 12414.
10. A. Ando, T. Miura, T. Tatematsu, T. Shioiri, Tetrahedron Lett. **1993**, *34*, 1507.
11. B. Lygo, P. G. Wainwright, Tetrahedron Lett. **1998**, *39*, 1599.
12. M. Masui, A. Ando, T. Shioiri, Tetrahedron Lett. **1988**, *29*, 2835.
13. Pivalophenone reduction yields 27 % e.e. with QUIBEC: Dissertation R. Klauck, U. of Bielefeld, 1997. A singular catalyst reaches 39.5 % e.e.: E. V. Dehmlow, S. Schrader, Pol. J. Chem. **1994**,*68*, 2199.
14. S. Arai, T. Shioiri, Tetrahedron Lett. **1998**, *39*, 2145.
15. W. Nerinckx, M. Vandewalle, Tetrahedron: Asymmetry **1990**, *1*, 265.
16. R. S. E. Conn, A. V. Lovell, S. Karady, L. M. Weinstock, J. Org. Chem. **1986**, *51*, 4710.
17. E. V. Dehmlow, R. Klauck, S. Düttmann, B. Neumann, H.-G. Stammler, Tetrahedron. Asymmetry **1998**, *9*, 2235.
18. E. V. Dehmlow, R. Klauck, B. Neumann, H.-G. Stammler, J. Prakt. Chem. **1998**, *340*, 572 and previous publications.
19. H. M. R. Hoffmann, T. Plessner, C. von Riesen, Synlett **1996**, 690.
20. J. P. Begue, M. Fetizon, Bull. Chim. Fr. **1969**, 1251.
21. V. Braschler, C. A. Grob, A. Kaiser, Helv. Chim. Acta **1963**, *46*, 2646.
22. K. Koch, J. H. Smitrovich, Tetrahedron Lett. **1994**, *35*, 1137.
23. QUIBEC = N-benzylquininium Cl, BCDC = N-benzyl-cinchonidinium Cl, BCNC = N-benzyl-cinchonium Cl.