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An improved synthesis of chiral 1-[α-(1-azacycloalkyl)benzyl]-2-naphthols

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Abstract—An improved synthesis of homochiral 1-[α-(1-azacycloalkyl)benzyl]-2-naphthols and 1-[α-(2-arylpiperidyl)benzyl]-2-naphthols has been achieved by employing diastereomerically pure α-benzotriazolyl 1-azacycloalka[2,1-*b*][1,3]oxazines as homochiral precursors, which were obtained by condensation between nonracemic Betti base and dialdehydes in the presence of benzotriazole.
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1. Introduction

Metal ion catalyzed asymmetric reactions are amongst the more recognized methods in current asymmetric chemistry, where homochiral ligands play an important role in the reactivity and stereoselectivity. Recently, many unnatural homochiral amino-phenol compounds have been reported as excellent ligands for this purpose.[1,2] Among them, the derivatives of chiral *N*,*N*-dialkylated Betti base **1** (Chart 1) are gaining increasing importance.[2]

Previously,[2] homochiral *N*,*N*-dialkylated Betti base **1** was prepared either by the resolution of the corresponding racemic isomers or by the Mannich reaction of chiral amines rather than by the alkylation of nonracemic Betti base (*S*)-**2** or (*R*)-**2**. However, we have recently achieved the synthesis of enantiopure 1-[α-(1-azacycloalkyl)benzyl]-2-naphthols **3a**–**c** from (*S*)-Betti bases (*S*)-**2**.[3] Compounds **3a**–**c** showed excellent chiral inductions in the asymmetric addition of Et_2Zn to arylaldehydes. However, their preparation suffered from using large amounts of solvent and as a result, application to bulk synthesis was limited. Herein, we report an improved procedure, in which **3a**–**c** and **4a**–**e**, a group of analogues of **3b** with increased steric hindrance, were prepared conveniently without the drawbacks that occurred in the previous procedures.

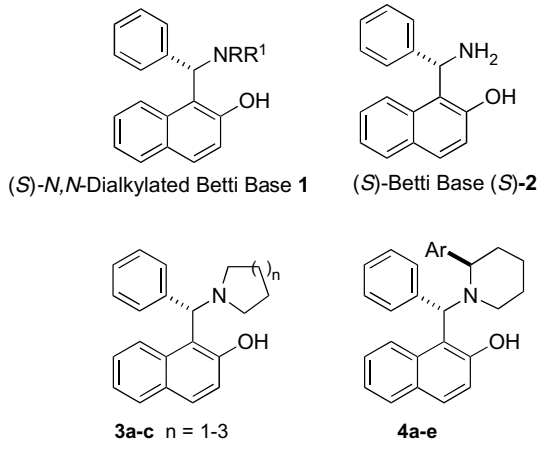

Chart 1.

2. Results and discussions

Recently, Katritzky has reported an elegant method to construct the α-benzotriazolyl 1-azacycloalka[2,1-*b*]-[1,3]oxazoles **5a**–**b** by the condensation between (*R*)-(+)-2-phenylglycinol and dialdehydes in the presence of BtH (benzotriazole) (Scheme 1).[4] The flexible behavior of Bt– as a leaving group in **5a** and **b**, allowing reduction and substitution under very convenient conditions, attracted our interest for the synthesis of **3a**–**c** and **4a**–**e**.

Following the Katritzky's procedure,[4b] a mixture of (*S*)-**2**, pentane-1,5-dialdehyde and BtH in CH_2Cl_2 was stirred at room temperature for 2 h, with the desired product pyrido[2,1-*b*][1,3]oxazine **6b** being separated

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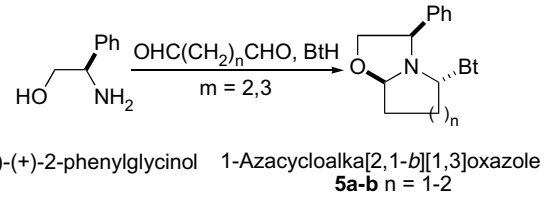
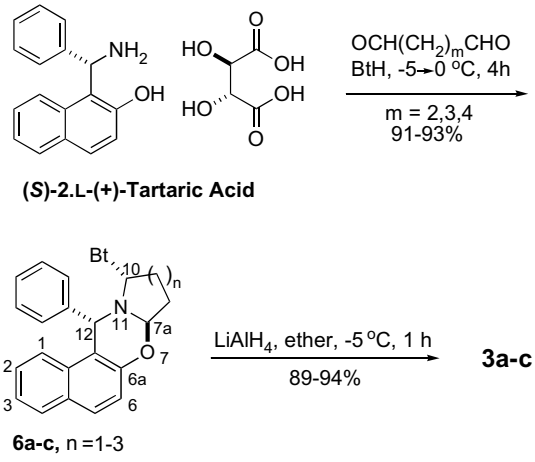


Scheme 1.

tediously from the mixture with 32% yield. However, when the reaction was performed at 0 °C for 5 h, **6b** was obtained as the unique product in 91% yield (Scheme 2). The diastereopurity of **6b** was proven by its benzyl proton appearing as a singlet peak at $\delta = 5.28$ ppm in the ^{1}H NMR. (*R*)-Configurations for both newly formed stereogenic carbons were deduced from single crystal X-ray diffraction analysis (Fig. 1).[5] Similarly, replacement of pentane-1,5-dialdehyde by butane-1,4-dialdehyde and hexane-1,6-dialdehyde, the five- and seven-membered azacyclic analogues **6a** and **6c**, were obtained, respectively, in high yields (93% and 91%) and diastereopurity.

Although $NaBH_4$ is frequently used to cleave C–Bt or C–O bonds in oxazoles at room temperature, it failed with our oxazines. For example, oxazine **6b** was treated with $NaBH_4$ at room temperature for 2 h to give a mixture, containing the partially reduced product. When



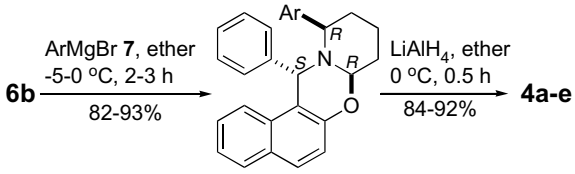
Scheme 2.

the reaction time was prolonged (5 h), the enantiomeric excess of **3b** decreased. However, we found that both C–Bt and C–O bonds in **6a–c** can be cut clearly by $LiAlH_4$ at −5 °C within 1 h to afford chiral ligands **3a–c** in high yields (89–94%) without any loss of enantiomeric excess (Scheme 2).

As **3b** showed the best chiral induction among **3a–c** and the Bt– group was readily substituted by Grignard reagents, a group of novel chiral ligands with high steric hindrance **4a–e** were designed and synthesized. As shown in Scheme 3, the intermediate **6b** was treated with PhMgBr **7a** at −5 °C for 2.5 h to yield **8a** as a single diastereoisomer in 91% yield. When compared with the arylation of **5b**, the current procedure can be performed under very mild conditions rather than at −78 °C for 12 h.[4b] Under similar conditions, the arylations of **6b** with other ArMgBr **7b–e** gave the corresponding **8b–e** in high yields and diastereoselectivity. The arylated carbons in **8a–e** were assigned (*R*)-configurations, deduced from the single crystal X-ray diffraction analysis of **8e** (Fig. 2).[6] Finally, the reduction of **8a–e** with $LiAlH_4$ yielded the target products **4a–e** in 84–92% yields. It is interesting to note that the most hindered compounds, **8e** and **4e**, gave the best yields.

3. Conclusion

Nonracemic Betti base when condensed with dialdehydes in the presence of BtH (benzotriazole) produced a



7,8,4	Ar	Yield of **8** (%)	Yield of **4** (%)
a	C_6H_5	91	86
b	4-MeC_6H_4	84	87
c	4-ClC_6H_4	85	85
d	4-PhC_6H_4	82	84
e	1-Naphthyl	93	92

Scheme 3.

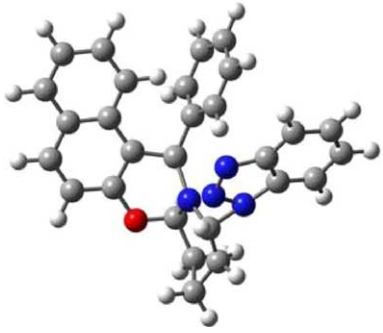


Figure 1. The structure of compound **6b**.

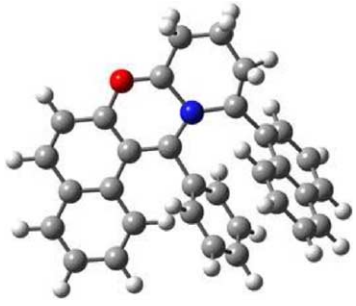


Figure 2. The structure of compound **8e**.

group of diastereopure chiral precursors α-benzotriazolyl 1-azacycloalka[2,1-*b*][1,3]oxazines **6a–c** in high yields. Reduction of **6a–c** with $LiAlH_4$ yielded chiral ligands 1-[α-(1-azacycloalkyl)benzyl]-2-naphthols **3a–c** conveniently. Moreover, **6b** can be arylated with ArMgBr, followed by reduction with $LiAlH_4$ to give a group of chiral potential ligands 1-[α-(2-arylpiperidyl)benzyl]-2-naphthols **4a–e**.

4. Experimental

4.1. General considerations

All melting points were determined on a Yanaco melting point apparatus and are uncorrected. IR spectra were recorded on a Nicolet FT-IR 5DX spectrometer as KBr pellets. The ^1H NMR spectra were recorded on a Bruker ACF-300 spectrometer in $CDCl_3$ with TMS as the internal reference. The *J* values are given in hertz. MS spectra were obtained on a VG-ZAB-HS mass spectrometer with 70 eV. The elemental analyses were performed on a Perkin–Elmer 240C instrument. Optical rotations were determined on a Perkin–Elmer 241 polarimeter. PE is petroleum ether (60–90 °C).

4.2. General procedure for the preparation of compounds 6a–c

A mixture of (*S*)-**2** [as salt of L-(+)-tartaric acid, 3.99 g, 10 mmol], dialdehyde (aqueous solution, 12 mmol), and benzotriazole (1.43 g, 12 mmol) in CH_2Cl_2 (40 mL) was stirred at 0 °C under nitrogen for 4 h. The resulting mixture was then washed with an aqueous solution of NaOH (1.0 M) to remove any excess benzotriazole. The organic layer was washed with H_2O and brine, and dried over anhydrous Na_2SO_4. After the removal of the solvent, the residue was purified by recrystallization to give the desired product **6**.

4.2.1. (7a*R*,10*R*,12*S*)-10-(1-Benzotriazolyl)-12-phenyl-7a,8,9,10-tetrahydro-12*H*-naphtho[1,2-*e*]pyrrolo[2,1-*b*][1,3]-oxazine 6a. Using butane-1,4-dialdehyde, **6a** was obtained as white crystals in 93% yield; mp 138–139 °C (EtOAc), $[\alpha]_D^{25} = +101.6$ (*c* 1.25, $CHCl_3$); Found: C, 77.21; H, 5.46; N, 13.46. $C_{27}H_{22}N_4O$: C, 77.49; H, 5.30; N, 13.39; ν_{max} (cm^{-1}) 3057, 2930, 1622, 1466; δ_H 7.10–8.21 (m, 13H), 6.68–6.70 (m, 2H), 6.21–6.25 (m, 1H), 5.40–5.42 (m, 1H), 5.29 (s, 1H), 2.35–2.92 (m, 4H); δ_C 152.3, 147.7, 142.1, 132.6, 131.7, 130.1, 129.6 (2C), 129.0, 128.9, 128.7 (2C), 127.8, 127.7, 127.2, 127.0, 124.7, 123.9, 123.2, 120.2, 119.0, 111.9, 110.0, 85.9, 54.8, 30.3, 28.9; *m/z*: 418 (M^+, 0.27%), 300 (36), 231 (100), 202 (61).

4.2.2. (7a*R*,11*R*,13*S*)-11-(1-Benzotriazolyl)-13-phenyl-8,9,10,11-tetrahydro-7a*H*,13*H*-naphtho[1,2-*e*]pyrido[2,1-*b*]-[1,3]oxazine 6b. Using pentane-1,5-dialdehyde (25% aqueous solution), **6b** was obtained as white crystals in 91% yield; mp 196–197 °C (EtOH), $[\alpha]_D^{25} = +152.6$ (*c* 1.6, $CHCl_3$); Found: C, 77.77; H, 5.71; N, 12.91. $C_{28}H_{24}N_4O$: C, 77.75; H, 5.59; N, 12.95; ν_{max} (cm^{-1}) 2900, 1620, 1440; δ_H 6.78–8.18 (m, 15H), 5.89 (m, 1H), 5.86 (s, 1H), 4.72–4.75 (m, 1H), 2.32–2.68 (m, 2H), 2.16–2.31 (m, 2H), 1.87–1.95 (m, 2H); δ_C 152.3, 147.2, 141.8, 132.7, 132.4, 130.1, 129.9 (2C), 129.6, 128.9, 128.5 (2C), 127.8, 127.6, 127.2, 124.7, 123.8, 122.8, 120.8, 119.0, 118.5, 112.1, 110.1, 81.8, 56.5, 31.2, 29.7, 18.2; *m/z*: 432 (M^+, 0.01%), 313 (26), 231 (100), 202 (20).

4.2.3. (7a*R*,12*R*,14*S*)-12-(1-Benzotriazolyl)-14-phenyl-7a,8,9,10,11,12-hexahydro-14*H*-naphtho[1′,2′:5,6][1,3]oxazino[2,1-*b*]azepine 6c. Using hexane-1,6-dialdehyde, **6c** was obtained as white crystals in 91% yield; mp 205–206 °C (EtOAc), $[\alpha]_D^{25} = +146.2$ (*c* 0.9, $CHCl_3$); Found: C, 77.87; H, 5.81; N, 12.71. $C_{29}H_{26}N_4O$: C, 78.00; H, 5.87; N, 12.55; ν_{max} (cm^{-1}) 3057, 2916, 1622, 1468; δ_H 7.73–7.79 (m, 3H), 7.09–7.36 (m, 12H), 5.52 (s, 1H), 4.62–4.66 (m, 1H), 2.44 (s, 1H), 1.47–1.77 (m, 8H); δ_C 152.6, 143.6, 143.0, 131.7, 129.2, 129.1, 128.6 (2C), 128.4, 128.2, 127.9 (2C), 127.7, 127.1, 126.5, 125.9, 123.9, 123.1, 122.8, 119.6, 119.4, 119.2, 114.3, 86.7, 82.4, 54.7, 54.1, 35.5, 24.6; *m/z*: 327 (M^+−BtH, 2.74%), 232 (45), 231 (100), 202 (19).

4.3. General procedure for the preparation of compounds 3a–c

To a suspension of $LiAlH_4$ (1.4 g, 30 mmol) in dry THF (20 mL) was added a solution of **6** (10 mmol) in dry THF (20 mL) at −5 °C under nitrogen. One hour later (monitored by TLC), a saturated aqueous solution of NH_4Cl (10 mL) was added to quench the reaction and the resulting mixture stirred for another 0.5 h at the same temperature. After removal of most of the THF in vacuum, the residue was extracted with CH_2Cl_2 (2×20 mL). The organic layers were washed with H_2O and brine, and dried over $MgSO_4$. After removal of the solvent, the residue was purified by chromatography (silica gel, 5% EtOAc in PE) to give the desired products **3a–c**.

4.3.1. (*S*)-1-(α-Pyrrolidinylbenzyl)-2-naphthol 3a. By reduction of **6a**, **3a** was obtained as white crystals in 89% yield; mp 159–160 °C (EtOAc–PE); $[\alpha]_D^{25} = +179.8$ (*c* 1.5, $CHCl_3$) {lit.[3b] mp 159–161 °C, $[\alpha]_D^{25} = +179.1$ (*c* 1.3, $CHCl_3$)}.

4.3.2. (*S*)-1-(α-Piperidylbenzyl)-2-naphthol 3b. By reduction of **6b**, **3b** was obtained as white crystals in 94% yield; mp 194–195 °C (EtOAc); $[\alpha]_D^{25} = +194.3$ (*c* 2.0, $CHCl_3$) {lit.[3b] mp 194–195 °C; $[\alpha]_D^{25} = +193.8$ (*c* 1.2, $CHCl_3$)}.

4.3.3. (*S*)-1-(α-Azepanylbenzyl)-2-naphthol 3c. By reduction of **6c**, **3c** was obtained as white crystals in 93% yield;

mp 118–119 °C (EtOAc–PE); $[\alpha]_D^{25} = +183.2$ (*c* 1.0, $CHCl_3$) {lit.[3b] mp 117–117.5 °C; $[\alpha]_D^{25} = +184.4$ (*c* 0.34, $CHCl_3$)}.

4.4. General procedure for the preparation of compounds 8a–e

To a cold solution (ice-water bath) of **6b** (0.86 g, 2 mmol) in dry Et_2O (80 mL) was added ArMgBr **7** (4 mmol) dropwise under nitrogen. The resultant mixture was stirred for 2–3 h (monitored by TLC), after which a saturated aqueous solution of NH_4Cl (10 mL) was added to quench the reaction at 0 °C. The separated organic layer was washed with an aqueous solution of NaOH (1.0 M, 30 mL), water (30 mL), and dried over anhydrous Na_2SO_4. After removal of the solvent, the residue was purified by chromatography (silica gel, PE) to give the pure product **8**.

4.4.1. (7a*R*,11*R*,13*S*)-11,13-Diphenyl-8,9,10,11-tetrahydro-7a*H*,13*H*-naphtho[1,2-*e*]pyrido[2,1-*b*][1,3]oxazine 8a. Using PhMgBr **7a**, compound **8a** was obtained as white crystals in 91% yield; mp 158–159 °C (PE); $[\alpha]_D^{25} = +110.1$ (*c* 0.21, $CHCl_3$); Found: C, 85.97; H, 6.34; N, 3.63. $C_{28}H_{25}NO$ requires: C, 85.90; H, 6.44; N, 3.58; ν_{max} (cm^{-1}) 2943, 2860, 1601, 1452, 1237; δ_H 7.06–7.67 (m, 16H), 5.47 (s, 1H), 5.14–5.18 (t, 1H), 3.44–3.48 (t, 1H), 2.04–2.30 (m, 2H), 1.70–1.76 (m, 2H), 1.53–1.57 (m, 2H); δ_C 150.7, 144.3, 138.3, 131.0, 130.6 (2C), 129.3 (2C), 129.2, 128.8, 128.2, 128.0, 127.9 (2C), 127.5 (2C), 127.0, 126.6, 123.2, 122.5, 118.5, 115.3, 82.7, 62.0, 57.3, 38.0, 32.6, 21.5; *m*/*z*: 391 (M^+, 0.14%), 231 (100), 202 (32), 77 (12).

4.4.2. (7a*R*,11*R*,13*S*)-11-(4-Methylphenyl)-13-phenyl-8,9,10,11-tetrahydro-7a*H*,13*H*-naphtho[1,2-*e*]pyrido[2,1-*b*][1,3]oxazine 8b. Using 4-MePhMgBr **7b**, **8b** was obtained as white crystals in 84% yield; mp 122–123 °C (PE); $[\alpha]_D^{25} = +97.1$ (*c* 0.3, $CHCl_3$); Found: C, 85.72; H, 6.55; N, 3.26. $C_{29}H_{27}NO$ requires: C, 85.89; H, 6.71; N, 3.49; ν_{max} (cm^{-1}) 2925, 1622, 1599, 1232; δ_H 6.94–7.74 (m, 15H), 5.12–5.18 (m, 1H), 3.77 (m, 1H), 3.44–3.50 (m, 1H), 2.34 (s, 3H), 1.59–2.03 (m, 5H), 1.18–1.22 (m, 1H); *m*/*z*: 405 (M^+, 0.14%), 231 (100), 202 (32), 91 (19).

4.4.3. (7a*R*,11*R*,13*S*)-11-(4-Chlorophenyl)-13-phenyl-8,9,10,11-tetrahydro-7a*H*,13*H*-naphtho[1,2-*e*]pyrido[2,1-*b*][1,3]oxazine 8c. Using 4-ClPhMgBr **7c**, **8c** was obtained as white crystals in 85% yield; mp 138–140 °C (PE); $[\alpha]_D^{25} = +124$ (*c* 0.1, $CHCl_3$); Found: C, 78.73; H, 5.51; N, 3.34. $C_{28}H_{24}ClNO$ requires: C, 78.95; H, 5.68; N, 3.29; ν_{max} (cm^{-1}) 2950, 1623, 1598, 1234; δ_H 7.06–7.77 (m, 15H), 5.34 (s, 1H), 5.15–5.18 (m, 1H), 3.69–3.74 (m, 1H), 1.78–2.19 (m, 2H), 1.59–2.03 (m, 4H); *m*/*z*: 425 (M^+, 0.54%), 231 (100), 202 (32).

4.4.4. (7a*R*,11*R*,13*S*)-11-(4-Phenylphenyl)-13-phenyl-8,9,10,11-tetrahydro-7a*H*,13*H*-naphtho[1,2-*e*]pyrido[2,1-*b*][1,3]oxazine 8d. Using 4-PhPhMgBr **7d**, **8d** was obtained as white crystals in 82% yield; mp 151–152 °C (PE); $[\alpha]_D^{25} = +95.4$ (*c* 0.2, $CHCl_3$); Found: C, 87.12; H, 6.05; N, 3.15. $C_{34}H_{29}NO$ requires: C, 87.33; H, 6.25; N, 3.00; ν_{max} (cm^{-1}) 2926, 1622, 1600, 1231; δ_H 6.72–7.70 (m, 20H), 5.18 (s, 1H), 4.04–4.10 (t, 1H), 3.44–3.48 (t, 1H), 2.34–2.38 (m, 2H), 1.57–1.70 (m, 4H); *m*/*z*: 467 (M^+, 0.09%), 231 (100), 202 (37).

4.4.5. (7a*R*,11*R*,13*S*)-11-(1-Naphthyl)-13-phenyl-8,9,10,11-tetrahydro-7a*H*,13*H*-naphtho[1,2-*e*]pyrido[2,1-*b*][1,3]oxazine 8e. Using 1-naphthylMgBr **7e**, **8e** was obtained as white crystals in 93% yield; mp 190–190.5 °C (PE); $[\alpha]_D^{25} = +290.5$ (*c* 0.3, $CHCl_3$); Found: C, 87.22; H, 6.35; N, 3.26. $C_{32}H_{27}NO$ requires: C, 87.04; H, 6.16; N, 3.17; ν_{max} (cm^{-1}) 3060, 2941, 2863, 1625, 1241; δ_H 7.62–7.91 (m, 6H), 7.41–7.49 (m, 3H), 6.98–7.19 (m, 7H), 6.78–6.80 (m, 2H), 5.57 (s, 1H), 5.20–5.25 (m, 1H), 4.20–4.24 (m, 1H), 2.29–2.33 (m, 1H), 1.23–1.98 (m, 5H); δ_C 150.8, 139.3, 138.3, 134.7, 131.4, 131.3 (3C), 129.6, 129.4 (2C), 128.8, 128.3 (3C), 128.0, 127.9, 126.7 (2C), 126.2, 125.8, 123.2, 122.6, 111.5, 115.2, 83.1, 57.3, 36.2, 32.6, 32.0, 21.8; *m*/*z*: 441 (M^+, 0.36%), 231 (100), 202 (29), 180 (29), 128 (15).

4.5. General procedure for the preparation of compounds 4a–e

To a stirred suspension of $LiAlH_4$ (0.14 g, 3 mmol) in dry THF (20 mL) was added a solution of **8** (10 mmol) in THF (30 mL) dropwise at −5 °C under nitrogen. After stirring at this temperature for 2 h (monitored by TLC), the mixture was quenched by the addition of a saturated aqueous solution of NH_4Cl (20 mL) with the resulting mixture stirred for another 30 min. The mixture was then extracted with CH_2Cl_2 (2×30 mL) and the combined organic layers washed with H_2O, brine and dried over Na_2SO_4. The solvent was removed to yield a crude product, which was purified by chromatography (silica gel, 2% EtOAc in PE) to give **4**.

4.5.1. (*S*)-1-[α-[(*R*)-2-Phenylpiperidyl]benzyl]-2-naphthol 4a. By reduction of **8a**, **4a** was obtained as white crystals in 86% yield; mp 154–155 °C (EtOAc), $[\alpha]_D^{25} = +46.8$ (*c* 0.3, $CHCl_3$); Found: C, 85.31; H, 7.06; N, 3.48. $C_{28}H_{27}NO$ requires: C, 85.46; H, 6.92; N, 3.56; ν_{max} (cm^{-1}) 3120, 2960, 2805, 2505, 1620, 1238; δ_H 15.61 (s, 1H), 6.92–8.14 (m, 16H), 5.57 (s, 1H), 2.90–3.69 (d, $J = 8.9$, 1H), 1.20–2.01 (m, 8H); *m*/*z*: 393 (M^+, 0.14%), 231 (100), 202 (32).

4.5.2. (*S*)-1-[α-[(*R*)-2-(4-Methylphenyl)piperidyl]benzyl]-2-naphthol 4b. By reduction of **8b**, **4b** was obtained as white crystals in 87% yield; mp 134–135 °C (EtOAc), $[\alpha]_D^{25} = +28.9$ (*c* 0.2, $CHCl_3$); Found: C, 85.26; H, 7.21; N, 3.35. $C_{29}H_{29}NO$ requires: C, 85.47; H, 7.17; N, 3.44; ν_{max} (cm^{-1}) 3059, 2936, 1623, 1599; δ_H 12.49 (s, 1H),

6.91–8.02 (m, 15H), 5.06 (s, 1H), 2.77–2.82 (m, 1H), 2.40 (m, 3H), 1.10–2.34 (m, 8H); m/z: 407 (M^+, 0.14%), 231 (100), 202 (32), 91 (19).

4.5.3. (*S*)-1-[α-[(*R*)-2-(4-Chlorophenyl)piperidyl]benzyl]-2-naphthol 4c. By reduction of **8c**, **4c** was obtained as white crystals in 85% yield; mp 109–110 °C (EtOAc), $[\alpha]_D^{25} = +54.6$ (c 0.2, $CHCl_3$); Found: C, 75.42; H, 6.17; N, 3.31. $C_{28}H_{26}ClNO$ requires: C, 75.58; H, 6.12; N, 3.27; ν_{max} (cm^{-1}) 3056, 2960, 1623, 1599, 1238; δ_H 14.90 (s, 1H), 6.97–8.30 (m, 16H), 5.53 (s, 1H), 2.88–3.65 (m, 1H), 1.20–2.01 (m, 8H); m/z: 427 (M^+, 0.03%), 313 (18), 231 (100), 202 (18).

4.5.4. (*S*)-1-[α-[(*R*)-2-(4-Phenylphenyl)piperidinyl]benzyl]-2-naphthol 4d. By reduction of **8d**, **4d** was obtained as white crystals in 84% yield; mp 159–160 °C (EtOAc), $[\alpha]_D^{25} = +64.6$ (c 0.1, $CHCl_3$); Found: C, 86.89; H, 6.71; N, 2.95. $C_{34}H_{31}NO$ requires: C, 86.96; H, 6.65; N, 2.98; ν_{max} (cm^{-1}) 3058, 2964, 1620, 1597, 1235; δ_H 14.64 (s, 1H), 6.97–8.30 (m, 20H), 5.57 (s, 1H), 2.79–3.04 (m, 1H), 1.20–2.01 (m, 8H); m/z: 469 (M^+, 0.05%), 231 (100), 202 (18).

4.5.5. (*S*)-1-[α-[(*R*)-2-(1-Naphthyl)piperidyl]benzyl]-2-naphthol 4e. By reduction of **8e**, **4e** was obtained as white crystals in 92% yield; mp 176–177 °C (EtOAc), $[\alpha]_D^{25} = +194.5$ (c 0.3, $CHCl_3$); Found: C, 86.89; H, 6.71; N, 2.90. $C_{32}H_{29}NO$ requires: C, 86.65; H, 6.59; N, 3.16; ν_{max} (cm^{-1}) 3060, 2940, 1623, 1599, 1238; δ_H 14.52 (s, 1H), 6.97–8.30 (m, 18H), 5.48 (s, 1H), 2.78–3.61 (m, 1H), 1.20–2.01 (m, 8H); m/z: 443 (M^+, 0.03%), 313 (18), 231 (100), 202 (18).

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References and notes

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5. Crystal data of compound **6b**: $C_{28}H_{24}N_4O$, $M = 432.51$, orthorhombic; $a = 10.743(7)$ Å, $b = 14.435(3)$ Å, $c = 14.537(4)$ Å; $V = 2254.3(17)$ Å^3, $T = 295(2)$ K, space group $P212121$, $Z = 4$; 2305 reflections measured, 2305 unique ($R_{int} = 0.0000$); absorption coefficient: 0.079 mm^{-1}; Final R indices [$I > 2\sigma(I)$]: $R_1 = 0.0566$, $wR_2 = 0.1509$; R indices (all data): $R_1 = 0.2504$, $wR_2 = 0.2169$. Crystallographic data for the structural analysis have been deposited with the Cambridge Crystallographic Data Centre, CCDC No. 221120.
6. Crystal data of compound **8e**: $C_{32}H_{27}NO$, $M = 441.55$, orthorhombic; $a = 11.460(2)$ Å, $b = 11.630(4)$ Å, $c = 17.370(4)$ Å; $V = 2315.1(10)$ Å^3, $T = 293(2)$ K; space group: $P2(1)2(1)2(1)$; $Z = 4$; absorption coefficient: 0.075 mm^{-1}; 2599 reflections measured, 2566 unique ($R_{int} = 0.1264$); Final R indices [$I > 2\sigma(I)$]: $R_1 = 0.0874$, $wR_2 = 0.2276$; R indices (all data): $R_1 = 0.2841$, $wR_2 = 0.3368$. Crystallographic data for the structural analysis have been deposited with the Cambridge Crystallographic Data Centre, CCDC No. 221121.