Studies on Steroidal Plant-growth Regulators. Part 33. Novel Method for Construction of the Side-chain of 23-Arylbrassinosteroids *via* Heck Arylation and Asymmetric Dihydroxylation as Key Steps

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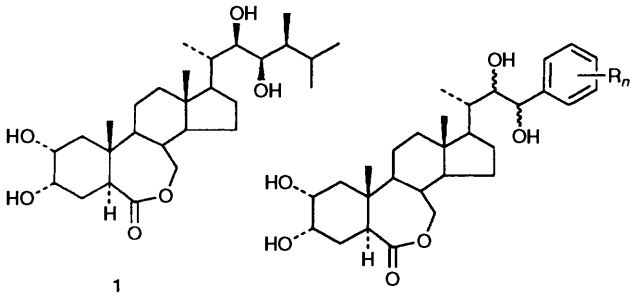
An efficient method for construction of the 23-arylbrassinosteroidal side-chain is described *via* Heck coupling and asymmetric osmylation as key steps. Several new (22*R*,23*R*)-23-arylbrassinosteroids were synthesized. The overall yields of 23-phenylbrassinosteroid **18** and the new compound **13a** from 22-olefin **7** were 10% (seven steps) and 37% (five steps), respectively.

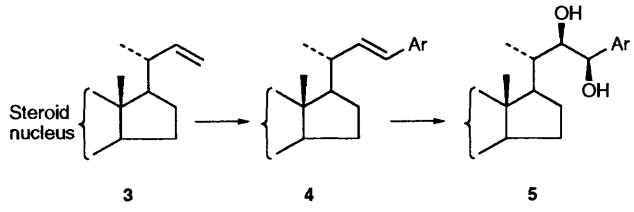
Since the discovery of brassinolide **1** as a steroidal plant-growth regulator,[1] much effort has been focused on developing some convenient, effective and general methods for its synthesis,[2] especially for building the side-chain. As a part of our efforts toward the synthesis of brassinosteroids, we have reported a practical method for stereoselective construction of the side-chain,[2j,k] which involved direct osmium-catalysed asymmetric dihydroxylation[3] of readily available (22*E*)-24-alkyl unsaturated steroidal side-chains, providing the naturally configured (22*R*,23*R*)-isomer as the major product. This approach shows the promise of considerable practical value due to its efficiency and simplicity. On the other hand, numerous new analogues have been synthesized for the investigation of structure–activity relationships.[2d,2i-k] Of these recent reports, Ikekawa and co-workers have disclosed that the new 23-phenylbrassinosteroid **2** possesses very high biological activity and is probably a



1

2 (22*R*, 23*R*) and (22*S*, 23*S*)
R = H, Halogeno, *etc.*; *n* = 1–3

promising candidate compound for application in agriculture.[4] However, as was noted from the synthesis of the above compound **2**, a large amount of BuLi is necessary for the construction of the (22*E*)-23-phenyl side-chain in the Wittig reaction of the corresponding 20-carbaldehyde, and, furthermore, osmylation of the 22*E* double bond with *N*-methylmorpholine *N*-oxide (NMMNO) as co-oxidant yielded the unnatural (22*S*,23*S*)-isomer as the major product, which has a much lower activity. Therefore, an efficient synthesis of 23-phenylbrassinosteroid **2**, particularly of the natural (22*R*,23*R*) configuration, should be of great significance due to its simple structure and high activity. Our synthetic strategy toward (22*R*,23*R*)-**2** involves both Heck coupling[5] and asymmetric osmylation[3] as key steps (Scheme 1). Namely, olefin **3**[6] underwent Heck arylation with aryl iodide to produce the (22*E*)-23-aryl side-chain **4**, followed by asymmetric osmylation of the resulting *E*-olefin to yield the (22*R*,23*R*)-23-arylbrassinosteroidal side-chain **5**.



3 **4** **5**

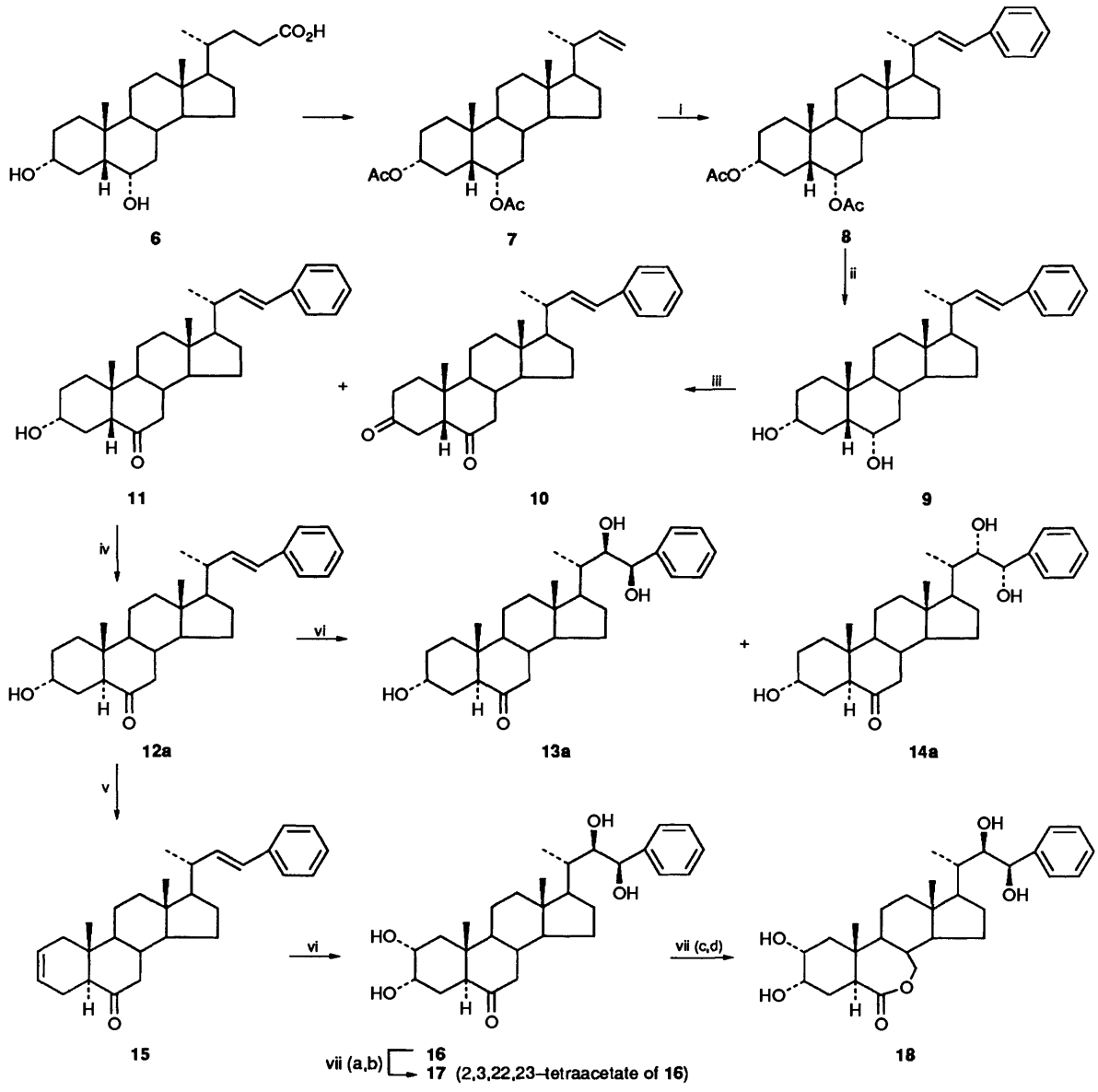
Scheme 1

Table 1 Osmylation of olefin **12a** to glycols **13a** and **14a**

Entry	Method[a]	Products[b] Ratio (**13a**:**14a**)	Yield (%)[c]
1	A	1:2	88
2	B	8.8:1	90
3	C	8.9:1	82
4	D	9.3:1	89

[a] Method A: cat. OsO_4, NMMNO; Method B: cat. OsO_4, DHQD-ClB, $K_3Fe(CN)_6$; Method C: cat. OsO_4, DHQD-NAP, $K_3Fe(CN)_6$; Method D: cat. OsO_4, DHQD-PHN, $K_3Fe(CN)_6$. [b] Ratio determined *via* separation by flash chromatography. [c] Isolated yield.

Preparation of 23-*Phenylbrassinosteroids* **18** *and* **13a** (*Scheme* 2).—Olefin **7**,[6] obtained from hyodeoxycholic acid **6**, on Heck coupling[5] with iodobenzene in refluxing triethylamine in the presence of 2% palladium acetate and 4% Ph_3P, produced the (22*E*)-23-phenyl olefin **8** in 71% yield. The advantages of Heck arylation are its simplicity and high yield. Compound **8** was subjected to saponification to diol **9**, followed by regioselective oxidation with pyridinium dichromate (PDC) to produce 3-ol-6-ketone **11** as the major product in 60% overall yield (2 steps), along with the 3,6-dione **10** (23.5%). The key intermediate **12a** can be easily obtained by acidic treatment of compound **11** in 92% yield. Dihydroxylation of the styrene **12a** was carried out with a catalytic amount of OsO_4 under different conditions and the results are summarized in Table 1. It is clear from the Table that, with NMMNO as co-oxidant,[4] only a 1:2 mixture of glycols **13a**/**14a** was obtained, in 88% yield, which affords the unnatural (22*S*,23*S*)-diol **14a** as the major product (entry 1, Table 1). When conditions of asymmetric dihydroxylation[3] were applied using dihydroquinidine *p*-chlorobenzoate (DHQD-ClB)[3a] as chiral ligand, the ratio of **13a**/**14a** could be increased to 8.8:1 (entry 2, Table 1). Use of the improved ligands dihydroquinidine 9-*O*-(1′-naphthyl) ether (DHQD-NAP)[3d] and dihydroquinidine 9-*O*-(9′-phenanthryl) ether (DHQD-PHN)[3d] can slightly enhance the enantioselectivity (entries 3, 4, Table 1).

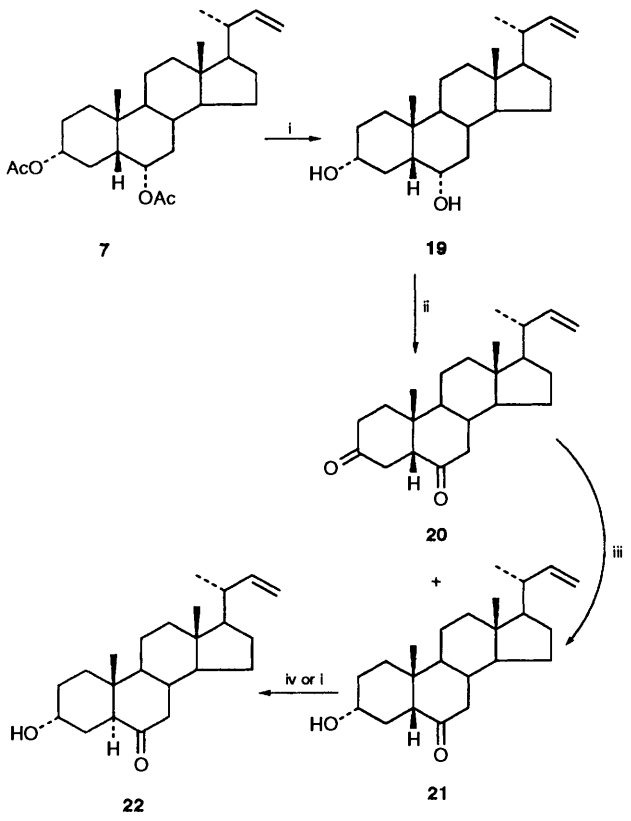


Scheme 2 *Reagents:* i, PhI, $Pd(OAc)_2$ (2%), Ph_3P (4%), Et_3N; ii, 4% KOH–MeOH; iii, PDC, CH_2Cl_2; iv, 2.5% HCl–MeOH; v, $CuSO_4$–silica gel, tetrachloroethylene; vi, DHQD-ClB, cat. OsO_4, $K_3Fe(CN)_6$, K_2CO_3, aq. Bu^{t}OH (1:1, v/v); vii, (a) Ac_2O, Py, CH_2Cl_2, cat. DMAP; (b) CF_3CO_3H, CH_2Cl_2; (c) 4% KOH–MeOH; (d) 6 mol dm^{-3} HCl, THF

Treatment of alkene **12a** with $CuSO_4$ adsorbed on silica gel[7] as the catalyst in tetrachloroethylene resulted in the 2,22-diene **15** (62% yield), which was dihydroxylated with DHQD-ClB as chiral ligand to produce (22*R*,23*R*)-2α,3α,22,23-tetrahydroxy compound **16** in 77% yield. Baeyer–Villiger oxidation of ketone **16** afforded the title compound **18** *via* the tetraacetate **17**. Thus, the represented simple and practical procedure provides a high overall yield (9%) of 23-phenylbrassinosteroid **18** from olefin **7** in seven steps. The new compound **13a** was also obtained with an overall yield of 32% from olefin **7** in five steps. It is noteworthy that compound **13a** has almost the same activity as 24-epibrassinolide on the rice lamina inclination test.[8] Since the introduction of a C-23 phenyl moiety has a significant effect on the bioactivity, it gives us considerable incentive to synthesize various substituted 23-arylbrassinosteroids for further structure–activity investigations.

Synthesis of Substituted 23-Arylbrassinosteroids.—As shown in Scheme 3, compound **7** underwent saponification to diol **19**, followed by regioselective oxidation with PDC, to furnish 3α-ol-6-ketone **21** as the major product. The diketone **20** as by-product can be converted into compound **21** by selective reduction of the 3-ketone with $NaBH_4$. Compound **21** was treated with acid or base for epimerization at C-5 to give the desired product **22** (52% yield from **7**, three steps).

We next undertook the Heck arylation of olefin **22** with a variety of aryl iodides and the results are summarized in Table 2. From the Table it is seen that the coupling of compound **22** with an electron-donating aryl iodide, for example iodobenzene, *p*-chlorophenyl iodide and *p*-bromophenyl iodide, can be smoothly carried out in the presence of 2% $Pd(OAc)_2$ and 4% Ph_3P in refluxing Et_3N, and after 20–30 h the Heck adduct was obtained in good yield (entries 1–3, Method A, Table 2). In contrast, when the same conditions were applied to the electron-withdrawing *p*-nitrophenyl iodide, no desired product was detected (entry 4, Method A, Table 2). However, after many attempts, we found that this coupling reaction of the electron-withdrawing aryl iodide can be realized under phase-transfer conditions.[9] Namely, treatment of olefin **22** with *p*-nitrophenyl iodide in the presence of 8% $Pd(OAc)_2$ and one mole equivalent



Scheme 3 *Reagents:* i, 4% KOH–MeOH; ii, PDC, CH_2Cl_2; iii, $NaBH_4$, MeOH; iv, 5% HCl–MeOH

of tetrabutylammonium chloride (TBAC) in dimethylformamide (DMF) at 80 °C for 6 h afforded the 22*E*-23-aryl compound **12d** in 52% yield (entry 4, Method B, Table 2). In addition, the coupling of *p*-bromophenyl iodide and α-naphthyl iodide with olefin **22** under the reaction conditions (Method B) also gave the desired products **12c** and **12e** in moderate to good yields. Unfortunately, the coupling of aryl bromides with olefin **22** is not satisfactory with either method (A or B). For example, there was little or no reaction of olefin **22** with *p*-tolyl bromide to give product **12f**, and we were unable to obtain any diol **13f**/**14f**. The resulting 22*E*-23-aryl compounds **12b–e**, when subjected to asymmetric dihydroxylation, afforded the natural (22*R*,23*R*)-isomers **13b–e** as the major products with 8:1–10:1 enantioselectivity. The bioactivity test of these new compounds is in progress.

Experimental

M.p.s were determined on a Buchi 535 instrument and are uncorrected. IR spectra were recorded on a Shimadzu 440 spectrometer. Optical rotations were measured on a Perkin-Elmer 241MC polarimeter and $[\alpha]_D$-values are given in units of 10^{-1} deg cm^2 g^{-1}. Mass spectra were run on a JMS-01U spectrometer. High-resolution mass spectra were recorded with a Finnigan MAT 8430 spectrometer. ^1H NMR spectra were determined with Varian XL-200 (200 MHz) and Bruker AM-300 (300 MHz) spectrometers, using $SiMe_4$ as internal standard (*J*-values in Hz). Elemental analyses were performed by the Analytical Department of this Institute. Usual work-up means that extracts were washed by 10% HCl (or saturated aq. $NaHCO_3$) and brine, dried over $MgSO_4$, and the solvent was removed under reduced pressure. The silica gel H (10–40 μ) was used for flash chromatography. Light petroleum refers to the fraction boiling in the range 60–90 °C.

(22E)-23-*Phenyl*-24-*nor*-5β-*chol*-22-*ene*-3α,6α-*diyl Diacetate* **8**.—To a solution of compound **7** (5.3 g, 12.3 mmol) in Et_3N (45 cm^3) were added Ph_3P (130 mg, 0.5 mmol), $Pd(OAc)_2$ (55 mg, 0.25 mmol) and iodobenzene (1.1 cm^3, 9.8 mmol) at room temp. under argon. After being stirred for 25–30 h at 100 °C, the reaction mixture was cooled to room temp. Usual work-up, followed by purification on a silica gel column with light petroleum–EtOAc (30:1), afforded *compound* **8** (4.05 g, 71%), m.p. 140–141 °C (from EtOH); $[\alpha]_D^{18}$ +13.2 (*c* 0.785, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 1730 (C=O) and 1600 (Found: C, 78.1; H, 9.4. $C_{33}H_{36}O_4$ requires C, 78.22; H, 9.15%); *m*/*z* 506 (M^+), 447 ($M^+ - CH_3CO_2$) and 131 ($C_{10}H_{11}$); δ_H(200 MHz; $CDCl_3$) 0.71 (3 H, s, 18-H_3), 0.99 (3 H, s, 19-H_3), 1.11 (3 H, d, *J* 6.2, 21-H_3), 2.01 (3 H, s, OAc), 2.05 (3 H, s, OAc), 4.71 (1 H, m, 3β-H), 5.15 (1 H, m, 6β-H), 6.05 (1 H, dd, *J* 15.8 and 8.5, 22-H), 6.30 (1 H, d, *J* 15.8, 23-H) and 7.28 (5 H, m, Ph).

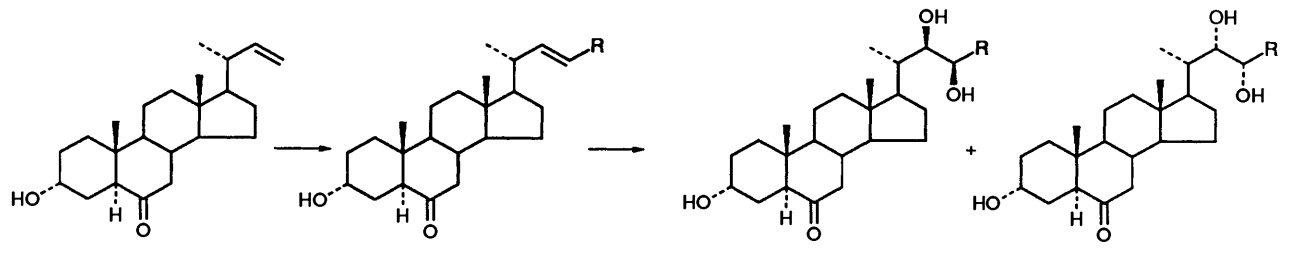
(22E)-23-*Phenyl*-24-*nor*-5β-*chol*-22-*ene*-3α,6α-*diol* **9**.—A solution of diacetate **8** (700 mg, 1.38 mmol) in 4% KOH–MeOH (40 cm^3) was heated at reflux for 1 h. The solvent was removed under reduced pressure and the residue was extracted with CH_2Cl_2. Work-up gave the *diol* **9** (574 mg, 98%) as needles from EtOAc, m.p. 181–182 °C (from EtOH); $[\alpha]_D^{28}$ +38.24 (*c* 0.35, MeOH); ν_{max}(KBr)/cm^{-1} 3350 (OH) and 1600 (Found: C, 80.8; H, 10.2. $C_{29}H_{42}O_2 \cdot \frac{1}{2}H_2O$ requires C, 80.69; H, 10.04%); *m*/*z* 422 (M^+), 404 ($M^+ - H_2O$) 131 ($C_{10}H_{11}$); δ_H(200 MHz; $CDCl_3$) 0.71 (3 H, s, 18-H_3), 0.92 (3 H, s, 19-H_3), 1.11 (3 H, d, *J* 6.6, 21-H_3), 2.22 (1 H, m, 20-H), 3.62 (1 H, m, 3β-H), 4.08 (1 H, m, 6β-H), 6.06 (1 H, dd, *J* 15.8 and 8.5, 22-H), 6.30 (1 H, d, *J* 15.8, 23-H) and 7.28 (5 H, m, Ph).

(22E)-23-*Phenyl*-24-*nor*-5β-*chol*-22-*ene*-3,6-*dione* **10** *and* (22E)-3α-*Hydroxy*-23-*phenyl*-24-*nor*-5β-*chol*-22-*en*-6-*one* **11**.—A solution of diol **9** (450 mg, 1.1 mmol) in CH_2Cl_2 (60 cm^3) was treated with PDC (800 mg) at room temp. for 2.5 h. The mixture was diluted with dry diethyl ether and the solid was filtered off. After removal of solvent, the residue was chromatographed with light petroleum–EtOAc (4:1) to afford the 3,6-*dione* **10** (108 mg, 24%) as needles, m.p. 197–197.5 °C; $[\alpha]_D^{10}$ +15.14 (*c* 0.864, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1600 (Found: C, 83.1; H, 9.15. $C_{29}H_{38}O_2$ requires C, 83.21; H, 9.15%); *m*/*z* 418 (M^+) and 131 ($C_{10}H_{11}$); δ_H(200 MHz; $CDCl_3$) 0.76 (3 H, s, 18-H_3), 0.97 (3 H, s, 19-H_3), 1.13 (3 H, d, *J* 6.8, 21-H_3), 2.22 (1 H, m, 20-H), 6.04 (1 H, dd, *J* 15.6 and 8.5, 22-H), 6.31 (1 H, d, *J* 15.6, 23-H) and 7.28 (5 H, m, Ph).

Further elution with light petroleum–EtOAc (3:1) gave *compound* **11** (280 mg, 62%), needles, m.p. 212–212.5 °C; $[\alpha]_D^{10}$ −33.33 (*c* 0.36, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3400 (OH), 1700 (C=O) and 1600 (Found: C, 83.2; H, 9.7. $C_{29}H_{40}O_2$ requires C, 82.81; H, 9.58%); *m*/*z* 421 (M^+ + 1), 420 (M^+), 403 (M^+ − OH) 131 ($C_{10}H_{11}$); δ_H(200 MHz; $CDCl_3$) 0.72 (3 H, s, 18-H_3), 0.86 (3 H, s, 19-H_3), 1.13 (3 H, d, *J* 6.6, 21-H_3), 2.15 (3 H, m, 5-H and 7-H_2), 3.64 (1 H, m, 3β-H), 6.04 (1 H, dd, *J* 15.8 and 8.5, 22-H), 6.31 (1 H, d, *J* 15.8, 23-H) and 7.28 (5 H, m, Ph).

(22E)-3α-*Hydroxy*-23-*phenyl*-24-*nor*-5α-*chol*-22-*en*-6-*one* **12a**.—The 5β-isomer **11** (230 mg, 0.55 mmol) was isomerized with 2.5% HCl–MeOH (15 cm^3) at room temp. overnight. The produced crystals were filtered off under reduced pressure, washed with cooled MeOH, and dried ($MgSO_4$) to give *title compound* **12a** (146 mg). Crystallization of the mother liquors afforded a further crop (66 mg) for a combined total of 212 mg of compound **12a** (92%) as needles, m.p. 229.5–230.5 °C (from MeOH–CH_2Cl_2); $[\alpha]_D^{10}$ +22.4 (*c* 0.50, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3400 (OH), 1700 (C=O) and 1600 (Found: C, 82.9; H, 9.7. $C_{29}H_{40}O_2$ requires C, 82.81; H, 9.58%); *m*/*z* 420 (M^+) and 131 ($C_{10}H_{11}$); δ_H(200 MHz, $CDCl_3$) 0.73 (3 H, s, 18-H_3), 0.74 (3 H, s, 19-H_3), 1.13 (3 H, d, *J* 6.6, 21-H_3), 2.30 (1 H, dd, *J* 12.7

Table 2 Arylation of olefin **22** with an aryl halide and subsequent asymmetric dihydroxylation of styrenes **12** to 22,23-diols **13** and **14**



22 **12a–f** **13a–f** **14a–f**

a b c d e f
R = Ph *p*-ClC_6H_4 *p*-BrC_6H_4 *p*-$NO_2C_6H_4$ α-Naphthyl *p*-MeC_6H_4

		Heck coupling			22,23-Diols	
			Yield (%)[a]			
Entry	Aryl halide	Product	Method A	B	Yields (%)[a]	Ratio[b] (13:14)
1	PhI	**12a**	79 (88)		90	8.8:1
2	*p*-ClC_6H_4I	**12b**	80 (90)		87	9.3:1
3	*p*-BrC_6H_4I	**12c**	74 (84)	50 (66)	88	10.0:1
4	*p*-$NO_2C_6H_4I$	**12d**	NR[c]	52 (63)[d]	83	8.6:1
5	α-Naphthyl iodide	**12e**		77	71	8.0:1
6	*p*-MeC_6H_4Br	**12f**	NR[c]	trace		

[a] Isolated yields; the yields in parentheses are based on unrecovered starting material. Method A: $Pd(OAc)_2$ (2%), Ph_3P (4%), Et_3N, 100 °C; Method B: $Pd(OAc)_2$ (8%), TBAC, $NaHCO_3$, DMF, 80 °C. [b] (22*R*,23*R*):(22*S*,23*S*). [c] No reaction. [d] NaOAc was used instead of $NaHCO_3$; the yield was 74%.

and 4.2, 7β-H), 2.73 (1 H, t, *J* 7.8, 5α-H), 4.17 (1 H, $W_{\frac{1}{2}}$ 8 Hz, 3β-H), 6.05 (1 H, dd, *J* 15.8 and 8.5, 22-H), 6.30 (1 H, d, *J* 15.8, 23-H) and 7.28 (5 H, m, Ph).

(22R,23R)-3α,22,23-*Trihydroxy*-23-*phenyl*-24-*nor*-5α-*chol*-22-*en*-6-*one* **13a** *and* (22S,23S)-3α,22,23-*Trihydroxy*-23-*phenyl*-24-*nor*-5α-*chol*-22-*en*-6-*one* **14a**.—*Method A* (OsO_4–*NMMNO*). A solution of olefin **12a** (20 mg, 0.05 mmol) in Bu^{t}OH–tetrahydrofuran–water (10:3:1; 2 cm^3) was treated with OsO_4 (0.05 mmol dm^{-3} in toluene; 0.2 cm^3; 0.01 mmol) and NMMNO (50 mg, 0.42 mmol) at room temp. for 24 h. Then saturated aq. $NaHSO_3$ was added and the mixture was stirred for 30 min. Work-up (EtOAc) followed by column chromatography with $CHCl_3$–MeOH (30:1) gave S,S-*diol* **14a** (13 mg, 60%), m.p. 239.5–240.5 °C; $[\alpha]_D^{28}$ −28.10 [*c* 0.52, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) (Found: C, 74.3; H, 9.5. $C_{29}H_{42}O_4 \cdot \frac{3}{4}H_2O$ requires C, 74.40; H, 9.37%); *m*/*z* 454 (M^+); δ_H(200 MHz; $CDCl_3$) 0.65 (3 H, s, 18-H_3), 0.72 (3 H, s, 19-H_3), 1.14 (3 H, d, *J* 7.0, 21-H_3), 2.28 (1 H, dd, *J* 12.5 and 4.5, 7β-H), 2.71 (1 H, t, *J* 8.0, 5α-H), 3.78 (1 H, dd, *J* 4.0 and 4.0, 22-H), 4.16 (1 H, $W_{\frac{1}{2}}$ 8 Hz, 3β-H), 4.74 (1 H, d, *J* 4.0, 23-H) and 7.28 (5 H, m, Ph).

Further elution with $CHCl_3$–MeOH (20:1) gave R,R-*diol* **13a** (6 mg, 28%), m.p. 259–261 °C; $[\alpha]_D^{28}$ −42.05 [*c* 0.35, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) (Found: C, 76.9; H, 9.4. $C_{29}H_{42}O_4$ requires C, 76.61; H, 9.31%); *m*/*z* 455 (M^+ + 1), 347 ($M^+ - C_7H_7O$) and 108 (C_7H_8O); δ_H(200 MHz; $CDCl_3$) 0.41 (3 H, s, 18-H_3), 0.69 (3 H, s, 19-H_3), 0.99 (3 H, d, *J* 6.9, 21-H_3), 2.35 (1 H, dd, *J* 12.5 and 4.6, 7β-H), 2.71 (1 H, t, *J* 7.5, 5α-H), 3.77 (1 H, d, *J* 8.0, 22-H), 4.17 (1 H, $W_{\frac{1}{2}}$ 8 Hz, 3-H), 4.61 (1 H, d, *J* 8.0, 23-H) and 7.30 (5 H, m, Ph).

Method B (OsO_4–*DHQD-ClB*). A mixture of olefin **12a** (120 mg, 0.29 mmol), DHQD-ClB (93 mg, 0.2 mmol), $K_3Fe(CN)_6$ (396 mg, 1.2 mmol), K_2CO_3 (166 mg, 1.2 mmol) and 0.05 mol dm^{-3} OsO_4 in toluene (0.1 cm^3, 0.005 mmol) in Bu^{t}OH–water (1:1; 7 cm^3) was stirred at room temp. for 5 h. Solid sodium sulfite (600 mg) was added and the contents were stirred at room temp. for 30 min. After work-up with EtOAc, the crude product was purified by flash chromatography on silica gel to give *S*,*S*-diol **14a** (12 mg, 9%) and *R*,*R*-diol **13a** (105 mg, 81%). The spectroscopic data for these were identical with those obtained above; there was no m.p. depression when admixed with the respective product obtained from Method A.

Method C (OsO_4–*DHQD-NAP*). With DHQD-NAP instead of DHQD-ClB, olefind **12a** (84 mg, 0.2 mmol) was dihydroxylated in the same way as described above. After 10 h, work-up afforded *S*,*S*-diol **14a** (7.5 mg, 8%) and *R*,*R*-diol **13a** (67 mg, 74%). Spectroscopic data for these were identical with those obtained from Method A or B.

Method D (OsO_4–*DHQD-PHN*). With DHQD-PHN as chiral ligand, the hydroxylation was carried out in the same manner as in Method B. Olefin **12a** (84 mg, 0.2 mmol) was used and gave *S*,*S*-diol **14a** (8 mg, 9%) and *R*,*R*-diol **13a** (74 mg, 81%). The spectroscopic data for compounds **13a** and **14a** were identical with those mentioned above.

(22E)-23-*Phenyl*-24-*nor*-5α-*chola*-2,22-*dien*-6-*one* **15**.—A mixture of the alcohol **12a** (750 mg, 1.8 mmol) and $CuSO_4$–SiO_2 catalyst (1.8 g, 2.0 mmol $CuSO_4$) was stirred and heated in refluxing tetrachloroethylene (35 cm^3) for 10 h. Then the catalyst was filtered off. Removal of solvent, followed by flash column chromatography using light petroleum–EtOAc (30:1) as eluent, afforded 2,22-diene **15** (445 mg, 62%) as needles from CH_2Cl_2–hexane, m.p. 187–187.5 °C; $[\alpha]_D^{10}$ +64.10 (*c* 0.83, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 1700 (C=O) and 1660 (C=C) (Found: C, 86.8; H, 9.55. $C_{29}H_{38}O$ requires C, 86.51; H, 9.51%); *m*/*z* 403 (M^+ + 1), 402 (M^+) and 131 ($C_{10}H_{11}$); δ_H(200 MHz; $CDCl_3$) 0.72 (3 H, s, 18-H_3), 0.74 (3 H, s, 19-H_3), 1.13 (3 H, d, *J* 6.6, 21-H_3), 2.35 (1 H, dd, *J* 12.5 and 4.2, 7-H), 5.64 (2 H, m, 2- and 3-H), 6.06 (1 H, dd, *J* 15.8 and 8.5, 22-H), 6.32 (1 H, d, *J* 15.8, 23-H) and 7.28 (5 H, m, Ph).

(22R,23R)-2α,3α,22,23-*Tetrahydroxy*-23-*phenyl*-24-*nor*-5α-*cholan*-6-*one* **16**.—The hydroxylation was carried out in the same manner as described for compounds **13a** and **14a** (Method

B); the diene **15** (130 mg, 0.32 mmol), DHQD-ClB (186 mg, 0.4 mmol), $K_3Fe(CN)_6$ (800 mg, 2.4 mmol), K_2CO_3 (335 mg, 2.4 mmol), a Bu^{t}OH–water mixture (1:1; 12 cm^3) and 0.05 mol dm^{-3} OsO_4 in toluene (0.2 cm^3, 0.1 mmol) were used. After 24 h at room temp., work-up gave *title compound* **16** (117 mg, 77%) as needles, m.p. 274–278 °C; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) (Found: C, 72.45; H, 9.1. $C_{29}H_{42}O_5 \cdot \frac{1}{2}H_2O$ requires C, 72.62; H, 9.04%); *m/z* 471 (M^+ + 1), 453 (M^+ − OH) and 108 (C_7H_8O); δ_H(200 MHz; [$^2H_6$]Me_2SO) 0.30 (3 H, s, 18-H_3), 0.59 (3 H, s, 19-H_3), 0.85 (3 H, d, *J* 7.0, 21-H_3), 3.49 (1 H, d, *J* 8.0, 22-H), 3.75 (1 H, $W_{\frac{1}{2}}$ 8 Hz, 3-H), 4.36 (1 H, d, *J* 8.0, 23-H), 4.38 (1 H, m, 2-H) and 7.30 (5 H, m, Ph).

(22R,23R)-2α,3α,22,23-*Tetrahydroxy*-23-*phenyl*-7-*oxa*-7a-*homo*-24-*nor*-5α-*cholan*-6-*one* **18**.—A solution of compound **16** (200 mg, 0.43 mmol) in CH_2Cl_2 (2 cm^3) was treated with pyridine (3 cm^3), Ac_2O (2 cm^3) and 4-(dimethylamino)pyridine (DMAP) (3 mg) at room temp. overnight. The solvent was removed under reduced pressure. The residue was dissolved in CH_2Cl_2 (8 cm^3), and was then treated with $(CF_3CO)_2O$ (1.56 cm^3) and 60% H_2O_2 (1.3 cm^3) at 0 °C for 1 h, then at room temp. for 48 h. Work-up followed by chromatography [light petroleum–EtOAc (2:1)] afforded (22*R*,23*R*)-6-oxo-23-phenyl-7-oxa-7*a*-homo-24-nor-5α-cholane-2α,3α,22,23-tetraaryl tetraacetate **17** (163 mg, 59%), δ_H(200 MHz; $CDCl_3$) 0.46 (3 H, s, 18-H_3), 0.96 (3 H, s, 19-H_3), 1.03 (3 H, d, *J* 7.6, 21-H_3), 2.00 (3 H, s, OAc), 2.03 (3 H, s, OAc), 2.09 (3 H, s, OAc), 2.11 (3 H, s, OAc), 3.00 (1 H, m, 5α-H), 4.08 (2 H, m, 7-H_2), 4.85 (1 H, m, 2-H), 5.40 (1 H, m, 3β-H), 5.43 (1 H, d, *J* 9.0, 22-H), 5.89 (1 H, d, *J* 9.0, 23-H) and 7.40 (5 H, m, Ph).

The tetraacetoxy compound **17** (80 mg, 0.12 mmol) was refluxed in 4% KOH–MeOH (5 cm^3) for 2 h. After removal of the solvent, the resulting residue was dissolved in THF (3 cm^3), and the solution was acidified with 6 mol dm^{-3} HCl (2 cm^3) overnight. Removal of part of the solvent gave needles of lactone **18** (49 mg, 82%), m.p. 235–237 °C; ν_{max}(KBr)/cm^{-1} 3400 (OH), 1720 (C=O), 1180 and 1060 [Found: 379.2469 ($M^+ - C_7H_7O$), 107.0521 (C_7H_7O). $C_{22}H_{35}O_5$, C_7H_7O require *m/z* 379.2485, 107.0497]; *m/z* 379 ($M^+ - C_7H_7O$) and 108 (C_7H_8O); δ_H(200 MHz; [$^2H_6$]Me_2SO) 0.33 (3 H, s, 18-H_3), 0.72 (3 H, s, 19-H_3), 0.84 (3 H, d, *J* 6.5, 21-H_3), 3.06 (1 H, dd, *J* 5 and 12, 5α-H), 3.48 (1 H, d, *J* 8.0, 22-H), 3.73 (1 H, $W_{\frac{1}{2}}$ 8.0 Hz, 3-H), 3.85 (1 H, d, *J* 12, 7α-H), 4.13 (1 H, m, 7α-H), 4.32 (1 H, m, 2-H), 4.36 (1 H, d, *J* 8.0, 23-H) and 7.28 (5 H, m, Ph).

24-*Nor*-5β-*chol*-22-*ene*-3,6-*dione* **20** *and* 3α-*Hydroxy*-24-*nor*-5β-*chol*-22-*en*-6-*one* **21**.—In the same manner as described for the preparation of compounds **10** and **11**, a solution of compound **19** (3.6 g, 10.4 mmol, prepared from diacetate **7** by saponification in 98% yield) in CH_2Cl_2 (200 cm^3) was treated with PDC (4.5 g) to give diketone **20** (752 mg, 21%) and hydroxy ketone **21** (2.21 g, 61.7%).

Dione **20**: needles from EtOAc, m.p. 205–207 °C (lit.,[10] 197–200 °C); ν_{max}(KBr)/cm^{-1} 1720, 1700 (C=O) and 1640 (C=C); *m/z* 342 (M^+), 327 (M^+ − Me), 314 (M^+ − CO), 287, 269, 189 and 149; δ_H(200 MHz; $CDCl_3$) 0.72 (3 H, s, 18-H_3), 0.96 (3 H, s, 19-H_3), 1.05 (3 H, d, *J* 6.5, 21-H_3), 4.84 (1 H, dd, *J* 10 and 2, 23-H), 4.92 (1 H, dd, *J* 18 and 2, 23-H) and 5.66 (1 H, ddd, *J* 18, 10 and 8, 22-H).

Hydroxy ketone **21**: needles, m.p. 157.5–158.5 °C (from EtOAc); $[\alpha]_D^{18}$ −82.34 (*c* 0.86, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3300 (OH), 1710 (C=O) and 1640 (C=C) (Found: C, 80.3; H, 10.7. $C_{23}H_{36}O_2$ requires C, 80.18; H, 10.53%); *m/z* 345 (M^+ + 1), 344 (M^+), 327 (M^+ − OH), 271 and 253; δ_H(200 MHz; $CDCl_3$) 0.68 (3 H, s, 18-H_3), 0.84 (3 H, s, 19-H_3), 1.05 (3 H, d, *J* 6.5, 21-H_3), 3.65 (1 H, m, 3β-H), 4.84 (1 H, dd, *J* 10 and 2, 23-H), 4.92 (1 H, dd, *J* 18 and 2, 23-H) and 5.66 (1 H, ddd, *J* 18, 10 and 8, 22-H).

Preparation of Hydroxy Ketone **21** *from Dione* **20** *by Reduction*.—To a stirred solution of dione **20** (1.76 g, 5.1 mmol) in MeOH (30 cm^3)–THF (5 cm^3) was added portionwise $NaBH_4$ (70 mg, 5.1 mmol) over a period of 1 h (10 min intervals) at 0–5 °C. After work-up, the residue was purified by chromatography [light petroleum–EtOAc (3:1)] to afford hydroxy ketone **21** (1.44 g, 82%). The spectroscopic data for product **21** were identical with those obtained above.

3α-*Hydroxy*-24-*nor*-5α-*chol*-22-*en*-6-*one* **22**.—*Acid conditions*. In the same manner as described for the preparation of compound **12a**, hydroxy ketone **21** (1.0 g, 2.9 mmol) was isomerized with 5% HCl–MeOH to afford *compound* **22** (876 mg, 87.6%) as needles, m.p. 177–177.5 °C; $[\alpha]_D^{18}$ −23.00 (*c* 0.69, $CHCl_3$); ν_{max}(KBr)/cm^{-1} 3400 (OH), 1700 (C=O) and 1640 (C=C) (Found: C, 80.2; H, 10.65. $C_{23}H_{36}O_2$ requires C, 80.18; H, 10.53%); *m/z* 344 (M^+), 329 (M^+ − Me), 316 (M^+ − CO), 287, 271, 149 and 95; δ_H(200 MHz; $CDCl_3$) 0.68 (3 H, s, 18-H_3), 0.72 (3 H, s, 19-H_3), 1.04 (3 H, d, *J* 6.5, 21-H_3), 2.30 (1 H, dd, *J* 4.3 and 12.5, 7β-H), 2.72 (1 H, t, *J* 8.0, 5α-H), 4.17 (1 H, $W_{\frac{1}{2}}$ 8 Hz, 3β-H), 4.83 (1 H, dd, *J* 10 and 2, 23-H), 4.90 (1 H, dd, *J* 18 and 2, 23-H) and 5.66 (1 H, ddd, *J* 18, 10 and 8, 22-H).

Basic conditions. A solution of compound **21** (500 mg, 1.5 mmol) in 4% KOH–MeOH (10 cm^3) was refluxed for 30 min, and then this mixture was kept at room temp. overnight. The crystals were filtered off under reduced pressure to give hydroxy ketone **22** (430 mg, 86%), m.p. 174.5–175.0 °C; spectroscopic data were identical with those obtained above.

Arylation of Olefin **22** *with Various Substituted Aryl Iodides*.—*Method A* (*general procedure*). The Heck coupling was carried out in the same way as described for compound **7**. Olefin **22** (344 mg, 1.0 mmol), $Pd(OAc)_2$ (4.5 mg, 0.02 mmol), Ph_3P (10.5 mg, 0.04 mmol), ArI (1.0 mmol) and Et_3N (5 cm^3) were used. After 2–3 days at 100 °C, work-up gave Heck adducts **12a–c** and a small amount of starting material **22** was recovered (Table 2, entries 1–3). Thus obtained were: (22*E*)-3α-Hydroxy-23-phenyl-24-nor-5α-chol-22-en-6-one **12a**, as needles, m.p. 230–231 °C; spectroscopic data were identical with those obtained in a previous experiment.

(22E)-23-(*p-Chlorophenyl*)-3α-*hydroxy*-24-*nor*-5α-*chol*-22-*en*-6-*one* **12b**, needles, m.p. 155–156.2 °C (from CH_2Cl_2–MeOH); $[\alpha]_D^{18}$ +31.15 [*c* 0.56, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3500 (OH) and 1700 (C=O) (Found: C, 75.7; H, 8.7; Cl, 7.9. $C_{29}H_{39}ClO_2 \cdot \frac{1}{4}H_2O$ requires C, 75.79; H, 8.66; Cl, 7.71%); *m/z* 455 (M^+), 454 (M^+ − 1) and 437 (M^+ − H_2O); δ_H(200 MHz; $CDCl_3$) 0.73 (3 H, s, 18-H_3), 0.74 (3 H, s, 19-H_3), 1.13 (3 H, d, *J* 6.5, 21-H_3), 2.31 (1 H, dd, *J* 12.5 and 4.0, 7β-H), 2.74 (1 H, t, *J* 8.0, 5α-H), 4.18 (1 H, $W_{\frac{1}{2}}$ 8 Hz, 3β-H), 6.04 (1 H, dd, *J* 16 and 8, 22-H), 6.27 (1 H, d, *J* 16, 23-H) and 7.25 (4 H, m, ArH).

(22E)-23-(p-*Bromophenyl*)-3α-*hydroxy*-24-*nor*-5α-*chol*-22-*en*-6-*one* **12c**, needles, m.p. 238–240 °C (from MeOH); $[\alpha]_D^{18}$ +26.95 [*c* 0.69, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3500 (OH) and 1700 (C=O) (Found: C, 70.0; H, 7.9; Br, 16.3. $C_{29}H_{39}BrO_2$ requires C, 69.73; H, 7.83; Br, 16.00%); *m/z* 500 and 498 (M^+), 419 (M^+ − Br) and 212 and 210 ($C_{10}H_{10}Br$); δ_H(200 MHz; $CDCl_3$) 0.72 (3 H, s, 18-H_3), 0.74 (3 H, s, 19-H_3), 1.13 (3 H, d, *J* 7.0, 21-H_3), 2.30 (1 H, dd, *J* 12.5 and 4.0, 7β-H), 2.74 (1 H, t, *J* 8.0, 5α-H), 4.18 (1 H, $W_{\frac{1}{2}}$ 8 Hz, 3β-H), 6.05 (1 H, dd, *J* 8.5 and 15.8, 22-H), 6.25 (1 H, d, *J* 15.8, 23-H), 7.18 (2 H, d, *J* 8.5, ArH) and 7.40 (2 H, d, *J* 8.5, ArH).

Method B (*general procedure*). A mixture of olefin **22** (172 mg, 0.5 mmol), ArI (0.5 mmol), $Pd(OAc)_2$ (9 mg, 0.04 mmol), TBAC (139 mg, 0.5 mmol) and $NaHCO_3$ (104 mg, 1.25 mmol) in DMF (3 cm^3) was heated at 80 °C for 4–10 h. The reaction mixture was cooled, and diluted with water (10 cm^3). Work-up followed by chromatography gave the desired products **12c–e** (entries 3–5, Table 2).

(22E)-23-(*p*-Bromophenyl)-3α-hydroxy-24-nor-5α-chol-22-en-6-one **12c**, needles, m.p. 239–241 °C (from MeOH); spectroscopic data were identical with those obtained from Method A.

(22E)-3α-*Hydroxy*-23-(p-*nitrophenyl*)-24-*nor*-5α-*chol*-22-*en*-6-*one* **12d**, pale yellow crystals, m.p. 240–241.4 °C (from MeOH); $[\alpha]_D^{18}$ +51.65 [*c* 0.96, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3500 (OH), 1700 (C=O), 1640 (C=C), 1600, 1510 and 1300 (Found: C, 74.6; H, 8.35; N, 2.8. $C_{29}H_{39}NO_4$ requires C, 74.80; H, 8.44; N, 3.01%); *m/z* 466 (M^+ + 1), 465 (M^+), 448 (M^+ − OH), 287 (M^+ − $C_{10}H_{10}NO_2$) and 177 ($C_{10}H_{10}NO_2$); δ_H(200 MHz; $CDCl_3$) 0.73 (6 H, s, 18- and 19-H_3), 1.15 (3 H, d, *J* 7.0, 21-H_3), 2.31 (1 H, dd, *J* 12.5 and 4.0, 7β-H), 2.74 (1 H, t, *J* 8.0, 5α-H), 4.18 (1 H, $W_{\frac{1}{2}}$ 7.5 Hz, 3β-H), 6.27 (1 H, dd, *J* 8.5 and 16.0, 22-H), 6.40 (1 H, d, *J* 16.0, 23-H), 7.40 (2 H, d, *J* 8.0, ArH) and 8.15 (2 H, d, *J* 8.0, ArH).

(22E)-3α-*Hydroxy*-23-*naphthyl*-24-*nor*-5α-*chol*-22-*en*-6-*one* **12e**, needles, m.p. 219–221 °C (from EtOAc); $[\alpha]_D^{18}$ −3.10 [*c* 0.29, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3500 (OH) and 1710 (C=O) (Found: C, 82.6; H, 9.1. $C_{33}H_{42}O_2 \cdot \frac{1}{2}H_2O$ requires C, 82.63; H, 9.03%); *m/z* 471 (M^+ + 1), 470 (M^+), 181 ($C_{14}H_{13}$) and 154; δ_H(200 MHz; $CDCl_3$) 0.78 (3 H, s, 18-H_3), 0.81 (3 H, s, 19-H_3), 1.25 (3 H, d, *J* 6.0, 21-H_3), 2.36 (1 H, dd, *J* 12.3 and 4.2, 7β-H), 2.78 (1 H, t, *J* 8.0, 5α-H), 4.22 (1 H, $W_{\frac{1}{2}}$ 7.5 Hz, 3β-H), 6.10 (1 H, dd, *J* 8 and 16, 22-H), 7.08 (1 H, d, *J* 16, 23-H), 7.51 (4 H, m, ArH), 7.78 (1 H, d, *J* 8.5, ArH), 7.87 (1 H, t, *J* 5, ArH) and 8.15 (1 H, m, ArH).

Asymmetric Dihydroxylation of Olefins **12b–e**.—In the same manner as described for the preparation of glycols **13a** and **14a** from olefin **12a** (Method B), DHQD-ClB (0.25 mmol), an olefin **12b–e** (0.5 mmol), $K_3Fe(CN)_6$ (495 mg, 1.5 mmol), K_2CO_3 (207 mg, 1.5 mmol), a mixture Bu^{t}OH–water (1:1; 12 cm^3) and 0.05 mol dm^{-3} OsO_4 in toluene (0.15 cm^3, 6.5 × 10^{-3} mmol) were used. After 24 h at room temp., work-up gave the *R,R*-glycol **13b–e** and a small amount of the *S,S*-glycol of **14b–e**. Thus were prepared the following compounds:

(22R,23R)-23-(p-*Chlorophenyl*)-3α,22,23-*trihydroxy*-24-*nor*-5α-*cholestan*-6-*one* **13b** (78.5%), needles, m.p. 245.5–247.0 °C; $[\alpha]_D^{20}$ −22.81 [*c* 0.60, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) (Found: C, 71.2; H, 8.55. $C_{29}H_{41}ClO_4$ requires C, 71.21; H, 8.45%); *m/z* 490 (M^+ + 1), 470 (M^+ − H_2O − 1), 436, 347, 329 and 142; δ_H(200 MHz; $CDCl_3$) 0.44 (3 H, s, 18-H_3), 0.70 (3 H, s, 19-H), 0.95 (3 H, d, *J* 7.3, 21-H_3), 2.26 (1 H, dd, *J* 13.2 and 4.5, 7β-H), 2.70 (1 H, t, *J* 8.2, 5α-H), 3.70 (1 H, d, *J* 8.6, 22-H), 4.15 (1 H, $W_{\frac{1}{2}}$ 7.5 Hz, 3β-H), 4.58 (1 H, d, *J* 8.6, 23-H), 7.26 (2 H, d, *J* 8.5, ArH) and 7.34 (2 H, d, *J* 8.5, ArH).

(22*S*,23*S*)-23-(*p*-Chlorophenyl)-3α,22,23-trihydroxy-24-nor-5α-cholestan-6-one **14b** (8.5%), needles, m.p. 156.5–157.5 °C; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) [Found: 332.2331 (M^+ − C_7H_6ClO − Me), 329.2471 (M^+ − C_7H_6ClO − H_2O). $C_{29}H_{41}ClO_4$, $C_{22}H_{33}O_2$ require *m/z* 332.2352, 329.2481]; *m/z* 471 (M^+ − H_2O), 368, 347, 329 and 142; δ_H(200 MHz; $CDCl_3$) 0.66 (3 H, s, 18-H_3), 0.72 (3 H, s, 19-H_3), 1.12 (3 H, d, *J* 7.0, 21-H_3), 2.28 (1 H, dd, *J* 12.3 and 4.5, 7β-H), 2.70 (1 H, t, *J* 8.0, 5α-H), 3.74 (1 H, dd, *J* 4.0 and 3.9, 22-H), 4.16 (1 H, $W_{\frac{1}{2}}$ 8.0 Hz, 3β-H), 4.71 (1 H, d, *J* 4.0, 23-H) and 7.35 (4 H, m, ArH).

(22R,23R)-23-(p-*Bromophenyl*)-3α,22,23-*trihydroxy*-24-*nor*-5α-*cholestan*-6-*one* **13c** (80%), needles, m.p. 231–232.5 °C; $[\alpha]_D^{20}$ 18.17 [*c* 0.99, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) (Found: C, 64.2; H, 7.9. $C_{29}H_{41}BrO_4 \cdot \frac{1}{2}H_2O$ requires C, 64.20; H, 7.82%); *m/z* 534 and 532 (M^+), 516 and 514 (M^+ − H_2O), 346, 329. 188 and 186; δ_H(200 MHz; $CDCl_3$) 0.44 (3 H, s, 18-H_3), 0.70 (3 H, s, 19-H_3), 0.98 (3 H, d, *J* 6.7, 21-H_3), 2.26 (1 H, dd, *J* 13.1 and 4.5, 7β-H), 2.70 (1 H, t, *J* 7.9, 5α-H), 3.69 (1 H, d, *J* 8.8, 22-H), 4.15 (1 H, $W_{\frac{1}{2}}$ 7.5 Hz, 3β-H), 4.55 (1 H, d, *J* 8.8, 23-H), 7.19 (2 H, d, *J* 8.3, ArH) and 7.49 (2 H, d, *J* 8.3, ArH).

(22S,23S)-23-(p-*Bromophenyl*)-3α,22,23-*trihydroxy*-24-*nor*-5α-*cholestan*-6-*one* **14c** (8%), needles, m.p. 210–211.5 °C; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) (Found: C, 65.1; H, 7.7; Br, 14.9. $C_{29}H_{41}BrO_4$ requires C, 65.28; H, 7.75; Br, 14.98%); *m/z* 517 and 515 (M^+ − OH), 347, 329. 299, 271, 247, 229 and 185; δ_H(200 MHz; $CDCl_3$) 0.68 (3 H, s, 18-H_3), 0.74 (3 H, s, 19-H_3), 1.10 (3 H, d, *J* 6.7, 21-H_3), 2.28 (1 H, dd, *J* 12.7 and 3.6, 7β-H), 2.72 (1 H, t, *J* 7.3, 5α-H), 3.71 (1 H, dd, *J* 4.0 and 4.0, 22-H), 4.17 (1 H, $W_{\frac{1}{2}}$ 8.0 Hz, 3β-H), 4.70 (1 H, d, *J* 4.0, 23-H) and 7.35 (4 H, m, ArH).

(22R,23R)-3α,22,23-*Trihydroxy*-23-(p-*nitrophenyl*)-24-*nor*-5α-*cholestan*-6-*one* **13d** (73.5%), m.p. 231–233 °C; ν_{max}(KBr)/cm^{-1} 3400 (OH), 1700 (C=O) 1600, 1510 and 1350 (Found: C, 68.95; H, 8.4. $C_{29}H_{41}NO_6 \cdot \frac{1}{4}H_2O$ requires C, 69.09; H, 8.30%); *m/z* 347 (M^+ − $C_7H_6NO_3$) and 329; δ_H[200 MHz; $(CD_3)_2CO$] 0.46 (3 H, s, 18-H_3), 0.72 (3 H, s, 19-H_3), 2.72 (1 H, m, 5α-H), 3.74 (1 H, d, *J* 8.5, 22-H), 4.12 (1 H, m, 3-H), 4.96 (1 H, d, *J* 8.8, 23-H), 7.70 (2 H, d, *J* 8.3, ArH) and 8.24 (2 H, d, *J* 8.3, ArH).

(22S,23S)-3α,22,23-*Trihydroxy*-23-(p-*nitrophenyl*)-24-*nor*-5α-*cholestan*-6-*one* **14d** (8.5%), m.p. 189–191 °C; ν_{max}(KBr)/cm^{-1} 3400 (OH), 1700 (C=O), 1600, 1520, 1350 and 1220 (Found: C, 67.8; H, 8.2; N, 2.4. $C_{29}H_{41}NO_3 \cdot H_2O$ requires C, 67.31; H, 8.32; N, 2.71); *m/z* 453 (M^+ − NO_2), 346, 329, 299, 271, 247, 229 and 120; δ_H[200 MHz; $(CD_3)_2CO$] 0.71 (3 H, s, 18-H_3), 0.73 (3 H, s, 19-H_3), 2.76 (1 H, m, 5α-H), 3.72 (1 H, dd, *J* 3.4 and 3.2, 22-H), 4.08 (1 H, m, 3β-H), 4.92 (1 H, d, *J* 3.2, 23-H), 7.72 (2 H, d, *J* 8.7, ArH) and 8.22 (2 H, d, *J* 8.7, ArH).

(22R,23R)-3α,22,23-*Trihydroxy*-23-(1-*naphthyl*)-24-*nor*-5α-*cholestan*-6-*one* **13e** (63%), needles, m.p. 221–223 °C; $[\alpha]_D^{20}$ −31.30 [*c* 0.19, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) (Found: C, 72.7; H, 8.7. $C_{33}H_{44}O_4 \cdot \frac{9}{4}H_2O$ requires C, 72.70; H, 8.97%); *m/z* 505 (M^+ + 1), 487 (M^+ − OH), 368, 347, 329 and 158; δ_H(200 MHz; $CDCl_3$) 0.31 (3 H, s, 18-H_3), 0.66 (3 H, s, 19-H_3), 1.06 (3 H, d, *J* 6.5, 21-H_3), 2.23 (1 H, dd, *J* 12.5 and 4.3, 7β-H), 2.68 (1 H, t, *J* 7.5, 5α-H), 4.10 (2 H, $W_{\frac{1}{2}}$ 8.0 Hz, 3β- and 22-H), 5.32 (1 H, br, 23-H), 7.51 (4 H, m, ArH), 7.85 (2 H, m, ArH) and 8.16 (1 H, d, *J* 8, ArH).

(22S,23S)-3α,22,23-*Trihydroxy*-23-(1-*naphthyl*)-24-*nor*-5α-*cholestan*-6-*one* **14e** (8%), needles, m.p. 172–173 °C; $[\alpha]_D^{20}$ −18.05 [*c* 0.47, $CHCl_3$–MeOH (1:1)]; ν_{max}(KBr)/cm^{-1} 3400 (OH) and 1700 (C=O) (Found: C, 76.6; H, 8.7. $C_{33}H_{44}O_4 \cdot \frac{3}{4}H_2O$ requires C, 76.49; H, 8.85%); *m/z* 487 (M^+ − OH), 347, 329 and 158; δ_H(200 MHz; $CDCl_3$) 0.64 (3 H, s, 18-H_3), 0.71 (3 H, s, 19-H_3), 1.23 (3 H, d, *J* 7.0, 21-H_3), 2.21 (1 H, dd, *J* 13.0 and 4.4, 7β-H), 2.68 (1 H, t, *J* 7.9, 5α-H), 4.04 (1 H, dd, *J* 4.2 and 4.2, 22-H), 4.15 (1 H, $W_{\frac{1}{2}}$ 7.5 Hz, 3β-H), 5.50 (1 H, d, *J* 4.2, 23-H), 7.51 (3 H, m, ArH), 7.66 (1 H, d, *J* 7.0, ArH), 7.83 (1 H, d, *J* 8.1, ArH), 7.90 (1 H, dd, *J* 2.3 and 7.5, ArH) and 8.19 (1 H, d, *J* 8.3, ArH).

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