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SYNTHESIS OF OXYGENATED EREMOPHILANES, GIGANTENONE, PHOMENONE AND PHASEOLINONE, PHYTOTOXINS FROM PATHOGENIC FUNGI†

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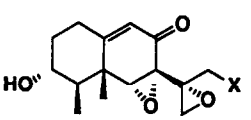
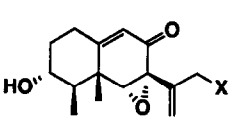
Abstract---- Stereoselective synthesis of several oxygenated eremophilane sesquiterpenes as phytotoxins, (+)-gigantenone **1**, (+)-phomenone **2** and (+)-phaseolinone **3**, was achieved in short steps from (+)-sporogen-AO 1 (13-desoxyphomenone) **4**

INTRODUCTION

Since protection of plants from phytopathogenic microorganisms is currently one of the most important tasks for human-beings, studies on the chemistry and the physiology of pathogenic phytotoxins have been extensively devoted and culminate in determining the structures of numerous toxins They include a wide variety of structures such as those of terpenes, polyketides, phenolics, carbohydrates, heterocycles and peptides [1,2] Recently, several oxygenated eremophilane sesquiterpenes were isolated as phytotoxins from plant pathogenic fungi (+)-Gigantenone **1** was isolated from weed pathogen, *Drechslera gigantea*, causing eye-spot disease on many kinds of grasses including cultivated turfgrasses and weeds such as crabgrass, *Digitaria* sp , quackgrass, *Agropyrone repens* and Bermuda grass, *Cynodon dactylon* [3] This toxin also contains diverse bioactivities of interest, including cytokinin-like activity of chlorophyll retention and auxin-like activity of rhizogenesis and shoot growth against mung bean, *Phaseolus aureus*, asparagus, *Asparagus officinalis*, red wood, *Sequoia sempervirens* and so on (+)-Phomenone **2** was first identified from a pathogenic fungus, *Phoma exigna* var *inoxydabilis*,[4] and later from *Phoma destructiva* P [5] as a growth inhibitor against the tomato plant It was also





1 X=H, Gigantenone **2** X=OH, Phomenone

3 X=OH, Phaseolinone **4** X=H, Sporogen-AO 1 (13-Desoxyphomenone)

Fig I

† Synthesis of Mono- and Sesquiterpenoids Part 20 Part 19, Mori,K , Suzuki,N *Liebigs Ann Chem* , 1990, 287

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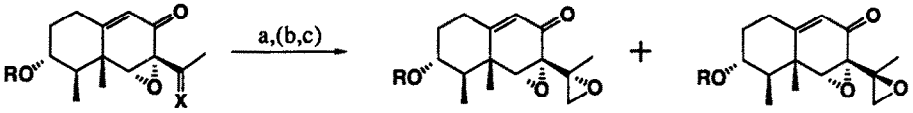
isolated from *Drechslera gigantea*.[6] (+)-Phaseolinone **3**, isolated from *Macrophomis phaseolina*[7] and later from *Drechslera gigantea*,[6] caused root rot and inhibition of seed-germination of beans, tobacco plants, ground nuts and other plants Its relative stereochemistry was determined by X-ray crystallography.[6] All of them are oxygenated analogs of (+)-sporogen-AO 1[8](13-desoxyphomenone[9]) **4** containing antifungal and phytotoxic activities[9] as well as sporogenic activity against *Aspergillus oryzae* [8] They all have interesting bioactivities and must be useful for the basic research on plant physiology, pathology and breeding of resistant races.

Chiral synthesis of them, however, has not been achieved yet. Only synthesis of (±)-phomenone (±)-**2** was reported,[10] but the overall yield of (±)-**2** was not sufficient to provide the sample for further study The situation prompted us to synthesize those eremophilanes, **1**, **2** and **3** in optically pure form efficiently. As it became possible to afford substantial amount of (+)-sporogen-AO 1 **4** by our effective synthesis,[11] we decided to use **4** as the common intermediate. As shown below, we report the short step synthesis of the natural enantiomers of gigantenone **1**, phomenone **2** and phaseolinone **3**.

SYNTHESIS OF (+)-GIGANTENONE

Epoxidation of sporogen-AO 1 **4** with MCPBA gave a mixture of two epoxides **1** and **8** in ca 47 to 53 ratio, while O-TBS sporogen-AO 1 **5** gave a mixture of **6** and **7** in ca. 30 to 70 ratio Thus the undesired epimers **8** and **7** were obtained predominantly. The mixture of **1** and **8** was hardly separable, but it could be separated in the case of protected diepoxides **6** and **7**, and they were rigorously characterized after deprotection Alternative procedures of indirect epoxidation afforded O-TBS epigigantenone **7** more selectively or almost exclusively as shown in Fig II (see entry 3,4). Thus, we turned to introduce an epoxide linkage directly to the



4 R=H, X=CH_2
5 R=TBS, X=CH_2
9 R=TBS, X=O

6 R=TBS
1 R=H

7 R=TBS
8 R=H

Entry	Substrate	Reagent	Product ratio		Yield
1	**4**	a, MCPBA	**1**, 47%	**8**; 53%	
2	**5**	a, MCPBA	**6**, 30%	**7**; 70%	70%
3	**5**	a, OsO_4-NMO b, TsCl, Py c, MeONa / MeOH	**6**; 10%	**7**, 90%	
4	**5**	a, NBS-THFaq b, MeONa / MeOH	**6**, trace	**7**, ~100%	
5	**9**	a, CH_2=SMe_2 / DMSO	---	---	0%
6	**9**	a, $ClCH_2Li$ / THF -70°C→ r t b, HF / MeCN	**1**, ~100%	**8**; trace	64%

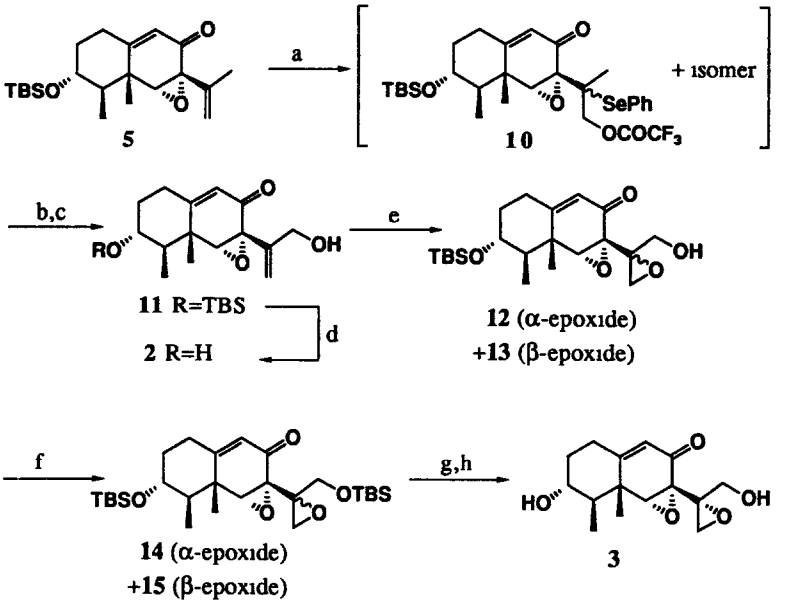
Fig II

diketoepoxide **9**, which was used as the key intermediate for our sporogen-AO 1 synthesis [11] Treatment of **9** with dimethylsulfonium methylide[12] caused decomposition of the substrate and did not give any products Chloromethyllithium prepared *in situ*,[13] however, added smoothly to **9** at -70°C giving the adduct which spontaneously cyclized to give gigantenone TBS ether **6** at ambient temperature almost exclusively (64%). The ratio of the products, **6** and **7** was over 99 to 1, and thus, stereoselective epoxidation of side chain was established Deprotection with HF in acetonitrile gave (+)-gigantenone **1**, which was identical with the authentic sample (IR,NMR)

SYNTHESIS OF PHOMENONE AND PHASEOLINONE

An attempt on allylic oxidation of the side chain in **5** with SeO_2-*t*-BuOOH[14] was unsuccessful and several trials using aluminum isopropoxide,[15] diethylaluminum 2,2,6,6-tetramethylpiperidide,[16] trimethylsilyl triflate[17] or lithium diethylamide[18] for the rearrangement of the epoxide in **6** did not give the desired O-TBS phomenone **11** (Fig.III) On the other hand, addition of phenylselenenyl trifluoroacetate[19] to O-TBS sporogen-AO 1 **5** at -10°C for 3 h gave mainly anti-Markovnikoff adduct **10** and the mixture was directly oxidized with MCPBA, followed by methanolysis to give O-TBS phomenone (55%) Deprotection gave (+)-phomenone **2** in good overall yield from **5**

Finally, phomenone **2** was converted to phaseolinone, but MCPBA oxidation of **11** again afforded a mixture of O-TBS phaseolinone **12** and its epimer **13** in ca 1 to 2 ratio TBHP oxidation catalyzed by $VO(acac)_2$ in dry benzene[20] gave **12** and **13** in ca. 1 to 10 So Sharpless asymmetric epoxidation was examined Although



a, $PhSeOCOCF_3$ / CH_2Cl_2, -10°C / 3h b, MCPBA / CH_2Cl_2 c, K_2CO_3 / MeOH (55%) d, HF / MeCN (96%) e, *t*-BuOOH, R-(-)-DIPT, $Ti(O\text{-}i\text{-}Pr)_4$ / CH_2Cl_2 f, TBSCl, Im / DMF g, separation (61% from **11**) h; HF / MeCN (quant)

Fig III

catalytic process[21] did not afford the epoxidation products, stoichiometric process using D-(-)-DIPT, Ti(O-*i*Pr)$_4$, TBHP and MS4A in CH_2Cl_2[22] gave the desired epoxide **12** predominantly (95 5) in 60% yield. The separation of the isomer was difficult in this step, so the hydroxyl group in the side chain was protected as TBS ether Bissilylated phaseolinone **14** and its isomer **15** were easily separated by SiO_2 column chromatography Deprotection gave (+)-phaseolinone **3** in 84% yield from **12** Synthetic (+)-phomenone **2** and (+)-phaseolinone **3** were identical with authentic samples (IR,NMR)

In conclusion, optically pure oxygenated eremophilane phytotoxins, gigantenone **1**, phomenone **2** and phaseolinone **3**, were synthesized in short steps from sporogen-AO 1 4 Biological studies using those samples are under investigation and the result will be reported in due course

EXPERIMENTAL

All m ps were uncorrected. IR spectra were measured as KBr disks or as solutions of CCl_4 on a Jasco IRA-102 spectrometer ^{1}H-NMR spectra were recorded with TMS as an internal standard at 100MHz on a JEOL JNM FX-100 spectrometer or at 300MHz on a BRUKER AC300 spectrometer ^{13}C-NMR spectra were recorded with TMS as an internal standard at 22 5MHz on a JEOL JNM EX-90 spectrometer Optical rotations were measured on a Jasco DIP 140 polarimeter UV spectra were measured on a Hitachi 200-20 spectrophotometer CD spectra were measured on a Jasco J-20C spectropolarimeter Merck Kieselgel 60 was used for SiO_2 column chromatography

(3S,4R,4aR,5R,6R,1'R)-3-(1',2'-Epoxy-1'-methylethyl)-6-t-butyldimethylsilyloxy-3,4-epoxy-4a,5-dimethyl-4,4a,5,6,7,8-hexahydro-2(3H)-naphthalenone **6** A solution of **9** (29mg, 0 076mmol) and chloroiodomethane (0 03ml, 0 4mmol) in dry THF (3ml) was cooled to -70°C under argon and to this was added dropwise 1 0M methyllithium in ether (0 32ml, 0 32mmol) The solution was stirred at -70°C for 30 min, then gradually raised to room temp and stirred overnight. The reaction mixture was poured into sat NH_4Cl soln and extracted with ether, washed with water, sat $NaHCO_3$ soln and brine, dried ($MgSO_4$) and concentrated *in vacuo* The residue was chromatographed over SiO_2 (0 5g) Elution with hexane-EtOAc (10 1) gave **6** (19mg, 0 049mmol, 64%) as prisms, m p 83-84°C (EtOH-H_2O=4 1), $[\alpha]_D^{21\,3}$ +147° (c=0 85, $CHCl_3$), IR νmax (CCl_4 solution) 3170(w), 2980(m), 2950(m), 2910(w), 2875(m), 1680(s), 1634(w), 1472(w), 1461(w), 1437(w), 1383(w), 1360(w), 1257(m), 1205(w), 1118(m), 1102(m), 1080(m), 1026(w), 1008(w), 979(w), 958(w), 937(w), 911(w), 886(m), 861(w), 837(m), 713(w), 684(w) cm^{-1}, ^{1}H-NMR δ(100MHz,$CDCl_3$) 0 085(3H,s), 0 090(3H,s), 0 92(9H,s), 1 12(3H,s), 1 18(3H,d,*J*=7 0Hz), 1 59(3H,s), 1 2~2 53(5H,m), 2 59(1H,d,*J*=4 7Hz), 2 82(1H,d,*J*=4 7Hz), 3 56(1H,dt,*J*=4 2,10 7Hz), 3 62(1H,s), 5 71(1H,d,*J*=1 7Hz), Found C, 66 16, H, 8 90 Calc for $C_{21}H_{34}O_4Si$ C, 66 62, H, 9 05

(3S,4R,4aR,5R,6R,1'R)-3-(1',2'-Epoxy-1'-methylethyl)-3,4-epoxy-6-hydroxy-4a,5-dimethyl-4,4a,5,6,7,8-hexahydro-2(3H)-naphthalenone (Gigantenone) **1** To a solution of **6** (76mg, 0 20mmol) in CH_3CN (2ml) was added 47% HF soln (0 06ml) After stirring for 1 h at room temp, the reaction mixture was quenched with sat $NaHCO_3$ soln and extracted with EtOAc The extract was washed with water and brine, dried ($MgSO_4$) and concentrated *in vacuo* The residue was chromatographed over SiO_2 (1g) Elution with hexane-EtOAc (1 1) gave gigantenone **1** (53mg, 0 20mmol, 100%) as prisms, m p 118 5-119 5°C (hexane-EtOAc=1 1), $[\alpha]_D^{20\,7}$ +235° (c=0 42, $CHCl_3$){lit ^{3} m p 140°C (EtOAc), $[\alpha]_D$ +160° (c=0 4, $CHCl_3$)}, UV (c=4 73x10^{5}mol/l in MeOH) loge=4 10 (λmax 242nm), CD (at 24 5°C, c=0 025 in MeOH, Δε[$\lambda_{(nm)}$]) -5 31(219), +5 31(244), +4 03(332), IR νmax (KBr disk) 3530(s), 3420(s), 3065(w), 3010(m), 2980(m), 2920(m), 2890(m), 1665(s), 1625(m), 1490(w), 1455(m), 1448(m), 1430(m), 1380(m), 1362(m), 1332(w), 1310(w), 1298(w), 1260(m), 1235(w), 1210(w), 1174(w), 1151(w), 1118(m), 1092(w), 1081(w), 1058(m), 1040(m), 1025(m), 998(m), 981(w), 956(w), 933(m), 885(m), 866(m), 850(m), 828(w), 784(m), 753(w), 720(w), 695(m) cm^{-1}, ^{1}H-NMR δ(300MHz,$CDCl_3$) 1 11(3H,s), 1 27(3H,d,*J*=6 7Hz), 1 43(1H,dddd,*J*=3 8,11 6,11 9,14 8Hz), 1 58(3H,s), 1 70(1H,s), 1 79(1H,dq, *J*=6 7,10 5Hz), 2 14(1H,dddd,*J*=2 9,4 2,4 5,11 6Hz), 2 34(1H,ddd,*J*=2 9,3 8,14 3Hz), 2 47(1H,*J*=dddd,1 8,4 5,14 3,14 8 Hz), 2 60(1H,d,*J*=4 6Hz), 2 83(1H,d,*J*=4 6Hz), 3 60(1H,ddd,*J*=4 2,10 5,10 9Hz), 3 64(1H,s), 5 73(1H,d,*J*=1 8Hz), ^{13}C-NMR δ(22 5MHz,$CDCl_3$) 11 34, 18 41, 18 80, 30 85, 35 05, 41 11, 44 39, 51 88, 54 00, 64 26, 64 53, 70 86, 120 86, 163 59, 193 39, Found C, 68 33, H, 7 70 Calc for $C_{15}H_{20}O_4$ C, 68 16, H, 7 63

(3S,4R,4aR,5R,6R)-6-t-Butyldimethylsilyloxy-3,4-epoxy-3-isopropenyl-4a,5-dimethyl-4,4a,5,6,7,8-hexahydro-2(3H)-naphthalenone **5** A mixture of **4** (87mg, 0 35mmol), imidazole (70mg, 1mmol) and *t*-BuMe_2SiCl (77mg, 0 5mmol) in DMF (3ml) was stirred overnight at room temp The reaction mixture was poured into water and extracted with ether The extract was washed with water (x4) and brine, dried ($MgSO_4$) and concentrated *in vacuo* The residue was chromatographed over SiO_2 (5g) Elution with hexane-EtOAc (20 1) gave recovered **4** (9mg, 10%) and **5** (113mg, 0 31mmol, 89%, 99% based on the unrecovered **4**) as needles, m p 82-84°C (isopropylether), $[\alpha]_D^{23\,0}$ +164° (c=0 4, $CHCl_3$), IR νmax (CCl_4 solution) 2970(s), 2945(s), 2910(m), 2870(s), 1680(s), 1635(w), 1472(w), 1461(m), 1438(w), 1407(vw), 1382(w), 1372(w), 1361(w), 1352(w), 1331(w), 1255(m), 1204(w), 1186(w), 1115(s), 1100(m), 1080(s), 1030(m), 1006(m), 955(w), 935(w), 910(w), 888(s), 836(s), 684(w) cm^{-1}, ^{1}H-NMR δ(100MHz,$CDCl_3$) 0 075(3H,s), 0 08(3H,s), 0 89(9H,s), 1 17(3H,d,*J*=6 8Hz), 1 21(3H,s), 1 87(3H,t,*J*=1 2Hz), 1 05~2 63(5H,m), 3 31(1H,s), 3 58(1H,dt,*J*=4 4,10 5Hz), 5 10(2H,m), 5 74(1H,d,*J*=1 5Hz), Found C, 69 54, H, 9 33 Calc for $C_{21}H_{34}O_3Si$ C, 69 56, H, 9 45

(3S,4R,4aR,5R,6R)-3-(1'-Hydroxymethylethenyl)-6-t-butyldimethylsilyloxy-3,4-epoxy-4a,5-dimethyl-4,4a,5,6,7,8-hexahydro-2(3H)-naphthalenone **11** To a solution of **5** (166mg, 0 44mmol) in CH_2Cl_2 (5ml) was added dropwise $PhSeOCOCF_3$ solution in CH_2Cl_2 (5ml, 1 2mmol) at -10°C under argon After stirring for 4 h at -10°C, pyridine (0.16ml, 2mmol) and MCPBA (140mg, 0 9mmol) were added and the reaction mixture was stirred at -10°C for 1 h and at room temp overnight. The reaction mixture was diluted with ether, washed with water, 1N HCl soln, sat $NaHCO_3$ soln and brine, dried ($MgSO_4$) and concentrated *in vacuo* The residue was chromatographed over SiO_2 (20g) Elution with hexane-EtOAc (2 1) gave **11** (89mg, 0 24mmol, 55%) as plates, m p 122-123°C (hexane), $[\alpha]_D^{20.6}$ +147°(c=0 255, $CHCl_3$), IR νmax, 3640(w), 3500(w), 2960(s), 2940(s), 2895(m), 2860(m), 1676(s), 1633(w), 1470(w), 1461(m), 1437(w), 1385(w), 1370(w), 1360(w), 1332(w), 1255(m), 1205(w), 1185(w), 1143(w), 1115(m), 1100(m), 1080(s), 1028(m), 1008(w), 958(w), 921(w), 888(s), 838(s), 689(w) cm^{-1} (CCl_4 solution), ^{1}H-NMR δ(100MHz,$CDCl_3$) 0 11(6H,s), 0 93(9H,s), 1 17(3H,d,*J*=6 4Hz), 1 27(3H,s), 0 95~2 71(5H,m), 3 37(1H,s), 3 58(1H,dt,*J*=4 4,9 8Hz), 4 19(1H,d,*J*=13 0Hz), 4 31(1H,d,*J*=13 0Hz), 5 33(1H,s), 5 38(1H,d,*J*=1 2Hz), 5 77(1H,d,*J*=1 4Hz), Found C, 66 28, H, 8 87 Calc for $C_{21}H_{34}O_4Si$ C, 66 63, H, 9 05

(3S,4R,4aR,5R,6R)-3,4-Epoxy-6-hydroxy-3-(1'-hydroxymethylethenyl)-4a,5-dimethyl-4,4a,5,6,7,8-hexahydro-2(3H)-naphthalenone (Phomenone) **2** To a solution of **11** (37mg, 0 095mmol) in CH_3CN (1ml) was added 47% HF soln (0 04ml) After stirring for 20 min at room temp, the reaction mixture was quenched with sat $NaHCO_3$ soln and extracted with EtOAc The extract was washed with water and brine, dried ($MgSO_4$) and concentrated *in vacuo* The residue was chromatographed over SiO_2 (1g) Elution with hexane-EtOAc (1 1~0 1) gave phomenone **2** (24mg, 0 091mmol, 96%) as prisms, m p 147 9-148 1°C (EtOAc), $[\alpha]_D^{20.7}$ +243° (c=0 65, MeOH){lit.[4] m p 148-149°C (EtOAc), $[\alpha]_D^{20}$ +225±2° (MeOH)}, UV (c=4 16x10^{-5}mol/l in MeOH) logε=4 12 (λmax 245nm), CD (at 24 5°C, c=0 022 in MeOH, Δε[$\lambda_{(nm)}$]) -9 7(216), +9 5(247), +3 1(330), IR νmax (KBr disk) 3400(s) 3340(s) 2990(m), 2960(m), 2940(m), 2890(m), 1675(s), 1633(m), 1458(m), 1450(m), 1430(w), 1400(m), 1388(w), 1365(m), 1333(m), 1277(w), 1253(w), 1212(m), 1186(w), 1145(w), 1111(m), 1092(w), 1036(s), 1022(s), 1011(m), 980(m), 958(w), 927(s), 909(s), 897(s), 860(m), 832(w), 750(w), 731(w), 722(w), 700(s), 670(m) cm^{-1}, ^{1}H-NMR δ(300MHz,$CDCl_3$) 1 24(3H,s), 1 27(3H,d, *J*=7 0Hz),1 45(1H,dddd,*J*=4 3,11 1,12 3,14 4Hz), 1 54(2H,broad), 1 82(1H,dq,*J*=7 0,10 6Hz), 2 17(1H,dddd,*J*=2 7,4 5,4 8,12 3Hz), 2 36(1H,ddd,*J*=2 7,4 3,14 4Hz), 2 54(1H,ddt,*J*=1 9,4 8,14 4Hz), 3 38(1H,s), 3 64(1H,ddd,*J*=4 5,10 6,11 1Hz), 4.20(1H,d,*J*=4 6Hz), 4 33(1H,d,*J*=4 6Hz), 5 33(1H,s), 5 40(1H,broad,s), 5.79(1H,d,*J*=1 9Hz), ^{13}C-NMR δ(22 5MHz,$CDCl_3$) 11 31, 18 62, 31 00, 35 21, 41 26, 44 42, 62 36, 63 85, 68 80, 70 89, 120 95, 126 39, 142 91, 163 97, 193 84 , Found C, 67 82, H, 7 63, Calc for $C_{15}H_{20}O_4$ C, 68 16, H, 7 63

(3S,4R,4aR,5R,6R,1'RS)-3-(2'-Hydroxy-1'-methylenoxyethyl)-6-t-butyldimethylsilyloxy-3,4-epoxy-4a,5-dimethyl-4,4a,5,6,7,8-hexahydro-2(3H)-naphthalenone **12** and C-1' isomer **13** {Sharpless' catalyst complex-TBHP solution A; To a solution of (-)-diisopropyltartrate (0 35ml, 0 016mmol) and MS4A (100mg) in CH_2Cl_2 (10ml) was added dropwise titanium tetraisopropoxide (0 59ml, 0 020mmol) at 0°C The mixture was stirred at 0°C for 30 min and cooled to -20°C, then a 7 1M solution of anhydrous *t*-BuOOH (4 3mmol) in isooctane (0 6ml) was added dropwise } A solution of **11** (60mg, 0 16mmol) and MS4A (30mg) in dry CH_2Cl_2 (4ml) was cooled to -20°C under argon To this solution was added dropwise the TBHP solution A (0 93ml, 0 36mmol) The reaction mixture was stirred for 16 h at -20°C, then quenched with 10% aqueous (±)-tartaric acid and stirred for 30 min at -20°C and 1 h at room temp The organic phase was separated, combined with EtOAc extracts from the aqueous phase, and the whole was washed with water, sat $Na_2S_2O_3$ soln, dried ($MgSO_4$) and concentrated *in vacuo* The residue was diluted with ether and cooled to 0°C 1N NaOH soln was added to this and the mixture was stirred for 30 min at 0°C and 1 h at room temp The organic phase was separated, combined with EtOAc extraction of the aqueous phase, washed with brine, dried ($MgSO_4$) and concentrated *in vacuo* The residue was chromatographed over SiO_2 (5g) Elution with hexane-EtOAc (1 1~0 1) gave recovered **11** (11 3mg, 19%) and 95 5 mixture of **12** and **13** (38mg, 0 096mmol, 60%, 73% based on the unrecovered **11**) The ratio of the two isomers was determined from the 300MHz ^{1}H-NMR spectrum This mixture was used in the next step without further purification IR νmax (film) 3450(s), 1660(s), 1643(m), 1250(s) cm^{-1}, ^{1}H-NMR δ(300MHz,$CDCl_3$) 0 75(3H,s), 0 77(3H,s), 0 89(9H,s), 1 12(3H,s), 1 17(3H,d,*J*=6 8Hz), 1 1~1 6(trace,m), 1 7~1 9(1H,m), 2 0~2 1(1H,m), 2 2~2 5(3H,m), 2 62(1H,d,*J*=4 6Hz), 2 93(trace,d,*J*=1Hz), 3 11(1H,d,*J*=4 6Hz), 3 5~3 7(2H,m), 3 86(1H,m), 4 16(1H,m), 5 73(1H,d,*J*=1 8Hz)

(3S,4R,4aR,5R,6R-1'S)-6-t-Butyldimethylsilyloxy-3-(2'-t-butyldimethylsilyloxy-1'-methylenoxyethyl)-3,4-epoxy-4a,5-dimethyl-4,4a,5,6,7,8-hexahydro-2(3H)-naphthalenone **14** A mixture of **12** and **13** (36mg, 0 091mmol), imidazole (20mg, 0 3mmol) and *t*-$BuMe_2SiCl$ (22mg, 0 15mmol) in DMF (1ml) was stirred for 5 h at room temp The reaction mixture was poured into water and extracted with ether The extract was washed with water (x4) and brine, dried ($MgSO_4$) and concentrated *in vacuo* The residue was chromatographed over SiO_2 (1gx3) Elution with hexane-EtOAc (20 1) gave **14** (38mg, 0 075mmol, 84%) as prisms, m p 133-134°C (MeOH), $[\alpha]_D^{23.0}$ +110° (c=0 365, $CHCl_3$), IR νmax (CCl_4 solution) 2960(m), 2940(m), 2855(m), 1676(s), 1631(w), 1460(m), 1360(m), 1253(s), 1109(s), 1077(s), 1003(w), 886(m), 868(m), 833(s) cm^{-1}, ^{1}H-NMR δ (100MHz, $CDCl_3$) 0 077(6H,s), 0 083(6H,s), 0 90(18H,s), 1 15(3H,s), 1 23(3H,d,*J*=5 7Hz), 2 57(1H,d,*J*=4 9Hz), 0 9~2 6(5H,m), 3 01(1H,d,*J*=4 9Hz), 3 4~3 75(1H,m), 3 57(1H,s), 3 84(1H,d,*J*=12Hz), 4 29(1H,d,*J*=12Hz), 5 70(1H,d,*J*=1 7Hz), Found C, 63 88, H, 9 45 Calc for $C_{27}H_{48}O_5Si_2$ C, 63 73, H, 9 51

(3S,4R,4aR,5R,6R,1'R)-3,4-Epoxy-3-(2'-hydroxy-1'-methylenoxyethyl)-6-hydroxy-4a,5-dimethyl-4,4a,5,6,7,8-hexahydro-2(3H)-naphthalenone (Phaseolinone) **3** To a solution of **14** (12mg, 0 023mmol) in CH_3CN (1ml) was added 47% HF soln (0 02ml) After stirring for 30 min at room temp, the reaction mixture was quenched with sat $NaHCO_3$ soln and extracted with EtOAc The extract

was washed with water and brine, dried ($MgSO_4$) and concentrated *in vacuo* The residue was chromatographed over SiO_2 (1g) Elution with hexane-EtOAc (1 1~0 1) gave phaseolinone 3 (7mg, 0.023mmol, ~100%) as prisms, m p 129-130°C (EtOAc), $[\alpha]_D^{20.5}$ +208° (c=0 32, EtOH){lit.[7] m p 126-128°C (EtOAc), $[\alpha]_D$ +94.5° (c=0 8, EtOH)}; UV (c=6.0x10^{-5}mol/l in MeOH) logε=4 4 (λmax 243nm), CD (at 24.5°C, c=0 024 in MeOH, $\Delta\varepsilon[\lambda_{(nm)}]$) -3 18(219), +5 95(245), +4 42(332), IR νmax (KBr disk) 3540(s), 3420(m), 3395(m), 3345(m) 2990(w), 2950(w), 2880(w), 1668(s), 1650(s), 1455(w), 1436(w), 1390(w), 1360(w), 1342(w), 1262(w), 1221(w), 1192(w), 1174(w), 1155(w), 1111(w), 1075(w), 1056(m), 1033(s), 998(w), 957(w), 932(w), 900(m), 890(m), 860(w), 842(w), 818(w), 790(w), 745(w), 720(w), 692(w) cm^{-1}, ^{1}H-NMR δ(300MHz,$CDCl_3$) 1.14(3H,s), 1.27(3H,d,*J*=6 7Hz), 1 43(1H,dddd,*J*=4 3, 11.2,12 3,14 3Hz), 1 63(2H,broad), 1 79(1H,dq,*J*=6 7,10 5Hz), 2 15(1H,dddd,*J*=2.8,4 4,4 7,12 3Hz), 2 36(1H,ddd,*J*=2 8,4 3,14 5Hz), 2 51(1H,dddd,*J*=1 8,4.7,14.3,14 5Hz), 2.64(1H,d,*J*=4 6Hz), 3 13(1H,d,*J*=4.6Hz), 3 62(1H,ddd,*J*=4 4,10 5,11 2Hz), 3 63(1H,s), 3 87(1H,d,*J*=12.3Hz), 4 16(1H,d,*J*=12 3Hz), 5.77(1H,d,*J*=1 8Hz), ^{13}C-NMR δ(22 5MHz,$CDCl_3$) 11 31, 18.80, 30.94, 35 03, 41 14, 44 45, 48 81, 56 75, 61 73, 62 86, 63 70, 70 77, 120 62, 164 69, 193 60, Found.C, 64 17; H, 7 18, Calc for $C_{15}H_{20}O_5$ C, 64 27, H, 7 19

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