assignments were adopted from Kinoshita[4b] without structural proof.

(2S,3R,4R,5R)-3-Butyl-4-benzoyl-2-methoxy-5-methyltetrahydrofuran (25). **24β** (2.0 g, 11.0 mmol) was submitted to the reaction conditions described for the conversion of **21** to **22** and gave after chromatography (hexane–ethyl acetate (5:1)) **25** (2.13 g, 69%) as a clear oil: $[\alpha]^{20}_D$ −15.3° (*c* 1.3) (lit.[4b] −15.0° (*c* 0.45); ^{1}H NMR δ 0.92 (t, *J* = 7 Hz, 3 H, CH_3), 1.26–1.60 (m, 6 H, CH_2, *n*-butyl), 1.32 (d, *J* = 6.5 Hz, 3 H, 5-H), 2.36 (mc, 1 H, 3-H), 3.44 (s, 3 H, OCH_3), 4.47 (quint, *J* = 6 Hz, 1 H, 5-H), 4.73 (d, *J* = 2.5 Hz, 1 H, 2-H), 5.18 (dd, *J* = 5.5 Hz, *J* = 3 Hz, 1 H, 4-H), 7.47 (mc, 2 H, meta-H), 7.58 (mc, 1 H, para-H), 8.08 (mc, 2 H, ortho-H); ^{13}C NMR δ 13.81, 16.02, 22.54, 29.62, 30.09, 51.48, 55.17, 76.38, 78.98, 109.20, 128.34, 129.67, 130.12, 132.97, 166.03; IR (film) 3070 w, 2960 vs, 2930 vs, 2860 vs, 1720 vs, 1600 w, 1450 m, 1380 m, 1275 vs, 1110 s, 1070 s, 710 s cm^{-1}. Anal. Calcd for $C_{17}H_{24}O_4$: C, 69.84; H, 8.27. Found: C, 69.71; H, 8.21.

Synthesis of 1a/1b (Scheme II). (2R,3S,4S)-4-Butyl-2-hydroxy-5-hexen-3-yl Methanesulfonate (26). **7c** (7.6 g, 29.6 mmol) in $CHCl_3$ (150 mL) was treated with methanesulfonyl chloride (2.5 mL, 33 mmol) and triethylamine (8.2 mL, 60 mmol) at 0 °C and stirred at 22 °C for 10 h. The mixture was washed with water, dried ($MgSO_4$), evaporated, and chromatographed (hexane–ethyl acetate (5:1)) to give the 3-mesylate (6.0 g, 67%) as a colorless oil, which was converted into **26** (4.15 g, 93%) as described for the preparation of **16** from **7a**: colorless oil; $[\alpha]^{20}_D$ +27.1° (*c* 2.1); ^{1}H NMR δ 0.9 (t, *J* = 6.5 Hz, 3 H, CH_3), 1.28 (d, *J* = 7 Hz, 3 H, 1-H), 1.10–1.54 (m, 6 H, $(CH_2)_3CH_3$, *n*-butyl), 2.34 (d, *J* = 7 Hz, 1 H, OH), 2.36 (mc, 1 H, 4-H), 3.10 (s, 3 H, OSO_2CH_3), 4.03 (dquint, *J* = 7 Hz, *J* = 4 Hz, 1 H, 2-H), 4.70 (dd, *J* = 7 Hz, *J* = 4 Hz, 1 H, 3-H), 5.12 (dd, *J* = 17 Hz, *J* = 2 Hz, 1 H, 6-H), 5.20 (dd, *J* = 10.5 Hz, *J* = 2 Hz, 1 H, 6-H), 5.68 (dt, *J* = 17 Hz, *J* = 10.5 Hz, 1 H, 5-H); ^{13}C NMR δ 13.67, 17.78, 22.38, 28.69, 30.79, 38.74, 45.76, 67.47, 88.57, 117.91, 137.61; IR (film) 3540 vs, 3080 m, 3040 m, 2940 vs, 2875 vs, 1645 m, 1465 s, 1420 s, 1340 vs, 1265 s, 1175 vs, 1100 s, 960 vs, 920 vs, 865 s, 820 m, 770 m, 735 w, 700 w, 620 w, 605 w, 535 s cm^{-1}. Anal. Calcd for $C_{11}H_{22}O_4S$: C, 52.77; H, 8.86. Found: C, 52.68; H, 8.83.

(1R,2R,1′S)-2-(1′-Butyl-2′-propenyl)-3-methyloxirane (27). **26** (3.6 g, 14.4 mmol) in chloroform (80 mL) was treated dropwise with sodium (338 mg, 14.7 mmol) in methanol (20 mL) at 0 °C. The mixture was stirred at 22 °C for 3 h. Workup as described for the preparation of **18** from **17** furnished **27** (2.0 g, 91%) as a volatile oil: bp 55–60 °C/15 mbar; $[\alpha]^{20}_D$ +24.4° (*c* 3.6); ^{1}H NMR δ 0.9 (t, *J* = 6.5 Hz, 3 H, $(CH_2)_3CH_3$), 1.29 (d, *J* = 5.5 Hz, 3 H, 1-H), 1.21–1.70 (m, 6 H, $(CH_2)_3CH_3$), 1.86 (mc, 1 H, 4-H), 2.54 (dd, *J* = 7.5 Hz, *J* = 2 Hz, 1 H, 3-H), 2.80 (dq, *J* = 5.5 Hz, *J* = 2 Hz, 1 H, 2-H), 5.05 (mc, 2 H, 6-H), 5.70 (ddd, J = 17 Hz, *J* = 11 Hz, *J* = 8 Hz, 1 H, 5-H); ^{13}C NMR δ 13.91, 17.55, 22.72, 28.99, 31.75, 46.08, 53.46, 62.59, 115.83, 138.04; IR (film) 3080 s, 2960 vs, 2930 vs, 2860 vs, 1640 s, 1465 s, 1420 m, 1380 s, 1340 w, 1260 w, 1150 w, 1125 w, 1065 m, 995 s, 945 m, 915 s, 860 s, 810 w, 765 s, 730 w, 670 w cm^{-1}. MS *m/e* (relative intensity) 155 (4%, (M + H)$^+$), 137 (15%), 111 (13%), 97 (17%), 81 (19%), 57 (100%), 43 (85%).

(2S,3R,4R)-2-Butyl-3,4-epoxypentanoic Acid (28). **27** (1.7 g, 11.0 mmol) was ozonized in methanol as described for **19a** to give the aldehyde (1.46 g, 85%): ^{1}H NMR δ 0.94 (t, *J* = 7 Hz, 3 H, $(CH_2)_3CH_3$), 1.34 (d, *J* = 5.5 Hz, 3 H, 5-H), 1.24–1.54 (m, 4 H, $(CH_2)_2CH_3$, 1.54–1.94 (m, 2 H, $CH_2(CH_2)_2$), 2.27 (dq, *J* = 7.5 Hz, *J* = 2 Hz, 1 H, 2-H), 2.78 (dd, *J* = 7.5 Hz, *J* = 3 Hz, 1 H, 3-H), 2.89 (dq, *J* = 5.5 Hz, *J* = 3 Hz, 1 H, 4-H), 9.71 (d, *J* = 2 Hz, 1 H, CHO); ^{13}C NMR δ 13.73, 17.36, 22.70, 26.71, 29.04, 53.17, 54.25, 58.11, 201.90; IR (film) 2960 vs, 2930 vs, 2860 s, 2720 w, 1720 vs, 1460 m, 1375 m, 1345 w, 1255 w, 1150 w, 1120 w, 1030 w, 955 w, 860 m, 800 w, 755 w, 725 w cm^{-1}.

The aldehyde (1.30 g, 8.45 mmol) was oxidized with RuO_4 as described for **19b** to furnish epoxy acid **28** (861 mg, 60%) after chromatography (hexane–ethyl acetate (3:1), R_f 0.2): $[\alpha]^{20}_D$ +5.7° (*c* 2.1); ^{1}H NMR δ 0.94 (t, *J* = 7 Hz, 3 H, $(CH_2)_3CH_3$), 1.34 (d, *J* = 5.5 Hz, 3 H, CH_3, 5-H), 1.29–1.52 (m, 4 H, $(CH_2)_2CH_3$), 1.8 (mc, 2 H, $CH_2(CH_2)_2CH_3$), 2.22 (q, *J* = 7.5 Hz, 1 H, 2-H), 2.83 (dd, *J* = 7.5 Hz, *J* = 2.5 Hz, 1 H, 3-H), 2.96 (dq, *J* = 5.5 Hz, *J* = 2.5 Hz, 1 H, 4-H), 9.65 (s, 1 H, COOH); ^{13}C NMR δ 13.77, 17.22, 22.54, 29.08, 29.57, 48.16, 54.06, 59.43, 178.98; IR (film) 2960 vs, 2940 vs, 2870 vs, 1830 m, 1735 vs, 1710 vs, 1470 s, 1460 s, 1415 m, 1380 s, 1220 s, 1185 s, 1125 m, 1060 w, 955 s, 910 w, 860 s, 780 w, 735 w, 655 cm^{-1}. Anal. Calcd for $C_9H_{16}O_3$: C, 62.76; H, 9.36. Found: C, 62.81; H, 9.28.

(3R,4R,5S)-3-Butyl-4-hydroxy-5-methyltetrahydrofuran-2-one (1a). **28** (800 mg, 4.6 mmol) was treated with 2 N sulfuric acid as described for the conversion of **20** into **2a** to give **1a** (620 mg, 78%) as colorless platelets: mp 51 °C (lit.[4b] mp 50–51 °C); $[\alpha]^{20}_D$ −17.8° (*c* 0.53, CH_3OH) (lit.[4b] −18° (*c* 1.09, CH_3OH)); ^{1}H NMR δ 0.94 (t, *J* = 7 Hz, 3 H, CH_3, *n*-butyl), 1.47 (d, *J* = 6.0 Hz, 3 H, 5-CH_3), 1.27–1.72 (m, 5 H, $(CH_2)_3CH_3$), 1.88 (mc, 1 H, $CH_2(CH_2)_2$), 2.18 (d, *J* = 6.25 Hz, 1 H, OH), 2.57 (mc, 1 H, 3-H), 3.81 (dd, *J* = 8 Hz, *J* = 6.26 Hz, 1 H, 4-H), 4.21 (quint, *J* = 7 Hz, 1 H, 5-H); ^{13}C NMR δ 13.79, 18.25, 22.62, 28.21, 28.89, 48.65, 79.00, 79.91, 175.97; IR (KBr) 3470 vs, 2950 vs, 2930 vs, 2860 s, 1735 vs, 1465 m, 1455 m, 1420 w, 1395 s, 1380 s, 1355 m, 1335 s, 1310 s, 1295 s, 1270 w, 1240 s, 1185 s, 1150 w, 1135 m, 1100 s, 1060 vs, 1020 s, 955 w, 940 s, 900 w, 845 m, 775 w, 730 w, 700 s, 645 s, 600 s, 525 s cm^{-1}; MS (relative intensity) *m/e* 172 (7%, M$^{+\cdot}$), 155 (4%), 129 (14%), 116 (87%), 99 (60%), 82 (42%), 71 (34%), 57 (100%), 43 (37%). Anal. Calcd for $C_9H_{16}O_3$: C, 62.76; H, 9.36. Found: C, 62.74; H, 9.45. The acylation of **1a** to **1b** proceeds as described in ref 4b to give blastmycinone of $[\alpha]^{20}_D$ 10.2° (*c* 1.1) (lit.[4b] 10° (*c* 1.2)).

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Notes

The Synthesis of Multiple *O*-Phosphoseryl-Containing Peptides via Phenyl Phosphate Protection

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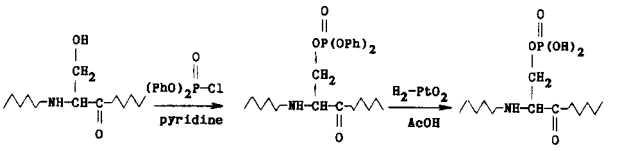
A commonly used procedure for the synthesis of *O*-phosphoseryl-containing peptides involves initial diphenyl phosphorochloridate/pyridine phosphorylation of serine-containing peptides followed by the hydrogenolytic reduction of the phenyl groups from the *O*-(diphenylphosphoro)seryl peptide[1-7] (Scheme I). However, as past

Scheme I



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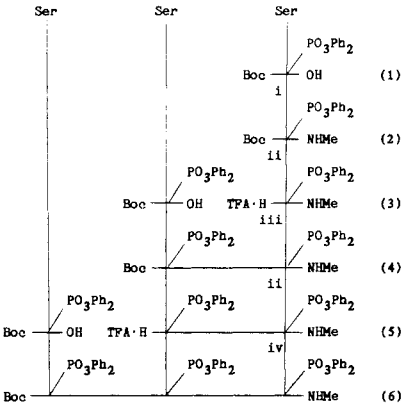
0022-3263/88/1953-4103$01.50/0

Scheme II[a]



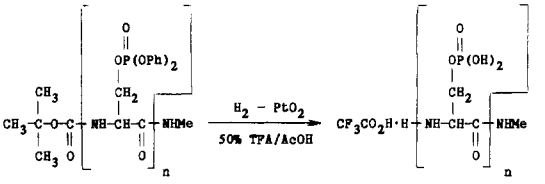
[a] (i) (a) NMM, IBCF (−20 °C 3 min), then (b) 24% aqueous *N*-methylamine (10 equiv) (−20 °C, 2 h); (ii) 40 % TFA/CH_2Cl_2 (20 °C 1 h); (iii) (a) NMM, IBCF (−20 °C, 3 min), then (b) peptide **3** (−20 °C, 2 h); (iv) (a) NMM, IBCF (−20 °C, 3 min), then (b) peptide **5** (−20 °C, 2 h).

syntheses using this approach were limited due to inefficient phosphorylation and/or incomplete hydrogenolytic phenyl cleavage,[1-5] we reexamined peptide synthesis procedures and subsequently developed an alternative synthetic approach which featured the (a) efficient solution-phase synthesis of protected Ser(PO_3Ph_2) peptides by the incorporation of Boc-Ser(PO_3Ph_2)-OH into peptide synthesis and (b) the use of 1.1 mmol of PtO_2/mmol phenyl group and 50% trifluoroacetic acid/acetic acid for the rapid and complete hydrogenolytic cleavage of phenyl phosphate groups. In this paper, we describe the synthesis of CF_3CO_2H·H-*P*Ser-NHMe and the use of the above approach for the first efficient syntheses of the multiple *P*Ser-containing peptides, CF_3CO_2H·H-*P*Ser-*P*Ser-NHMe and CF_3CO_2H·H-*P*Ser-*P*Ser-*P*Ser-NHMe. These latter class of compounds are of particular biochemical interest on account of the fact that *P*Ser clusters, which occur at regions 17–19 and 8–10 of bovine and human β-casein, respectively, are known to be prominant calcium binders and are considered to play an important role in maintaining the structural integrity of the casein micelle.[8]

The synthesis of the protected Ser(PO_3Ph_2) peptides were readily accomplished by the incorporation of Boc-Ser(PO_3Ph_2)-OH into the Boc mode of solution-phase peptide synthesis. Thus, Boc-Ser(PO_3Ph_2)-NHMe (**2**) was obtained in 80% yield by the isobutoxycarbonyl mixed anhydride coupling of Boc-Ser(PO_3Ph_2)-OH (**1**) with a tenfold excess of *N*-methylamine. In turn, the protected Ser(PO_3Ph_2) peptides (**4**) and (**6**) (Scheme II) were obtained in 96% and 98% yields, respectively, by the mixed anhydride coupling of Boc-Ser(PO_3Ph_2)-OH with the intermediate peptides **3** and **5**, acidolytic removal of the Boc group from peptides **2** and **4** being effected with the use of 40% TFA/CH_2Cl_2.

Subsequent hydrogenolysis of peptides **2**, **4**, and **6** in 50% TFA/AcOH containing 1.1 mmol of PtO_2 per phenyl phosphate group readily cleaved the phenyl protecting groups and gave CF_3CO_2H·H-*P*Ser-NHMe, CF_3CO_2H·H-*P*Ser-*P*Ser-NHMe, and CF_3CO_2H·H-*P*Ser-*P*Ser-*P*Ser-NHMe in near-quantitative yields (Scheme III). In all three cases, the peptides were satisfactorily characterized by ^{13}C NMR spectroscopy, ^{31}P NMR spectroscopy, and FAB mass spectrometry (Ar, positive mode), this latter technique being particularly useful in the structural characterization of *O*-phosphoseryl peptides[9] and for establishing their purity (that is, being free from monophenyl phosphate contamination). To our knowledge, CF_3CO_2H·H-*P*Ser-*P*Ser-*P*Ser-NHMe (**9**) represents the largest multiple *P*Ser-containing peptide that has been prepared, and adequately characterized, to date.

Scheme III



(2) n = 1 (7) n = 1
(4) n = 2 (8) n = 2
(6) n = 3 (9) n = 3

The efficient synthesis of peptides **7**, **8**, and **9** via a phenyl phosphorotriester protection approach clearly demonstrates that the synthetic approach described here is the favored method for the synthesis of complex and multiple *O*-phosphoseryl-containing peptides.

Experimental Section

General Methods. 83% platinum oxide was purchased from Pfaltz and Bauer, Hopkins and Williams, or Johnson Matthey Chemicals and Boc-Ser(PO_3Ph_2)-OH (**1**) was prepared by a synthetic procedure described elsewhere.[10] Acetic acid and trifluoroacetic acid were of A.R. grade and used without purification. The ^{13}C NMR spectra were obtained on a JEOL-FX 100 Fourier transform instrument operating at 25.00 MHz and referenced to internal dioxane set to 66.5 ppm. The ^{31}P NMR spectra were obtained on a JEOL-FX 100 Fourier transform instrument operating at 40.26 MHz and referenced to external 85% H_3PO_4. The FAB mass spectra were obtained on a JEOL-DX 300 mass spectrometer equipped with a FAB source and used glycerol as matrix support. Optical rotations were performed in $CHCl_3$ or H_2O and measured on a Perkin-Elmer 241 MC polarimeter at the sodium D line with a 1-dm path length cell kept at constant temperature.

Boc-Ser(PO_3Ph_2)-NHMe (2). *N*-Methylmorpholine (0.53 g, 5.26 mmol) in THF (2 mL) and isobutyl chloroformate (0.683 g, 5.00 mmol) in THF (2 mL) were successively added to a solution of Boc-Ser(PO_3Ph_2)-OH (2.30 g, 5.26 mmol) in THF (10 mL) at −20 °C. After an activation period of 3 min, 24% aqueous *N*-methylamine (3.1 mL, 25.0 mmol) was added to the solution, and the resulting solution was stirred for 2 h at −20 °C prior to the addition of 5% $NaHCO_3$ (5 mL). After 30 min at 20 °C, dichloromethane (100 mL) was added and the organic phase washed with 5% $NaHCO_3$ (2 × 30 mL) and 1 M HCl (2 × 30 mL), dried (Na_2SO_4), and filtered. Evaporation of the solvent under reduced pressure gave **2** as a white crystalline solid (2.03 g, 80%), mp 98.5–99.5 °C: $[\alpha]^{23}_D$ +1.42° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.44 (s, 9 H, Boc CH_3), 2.75 (d, 3 H, J_{NH-H} = 4.88 Hz, NHCH_3), 4.20–4.75 (m, 3 H, Ser α-CH and β-CH_2), 5.50 (br d, 1 H, Ser NH), 6.21 (br q, 1 H, NHCH$_3$), 7.10–7.50 (m, 10 H, Ar H); ^{13}C NMR ($CDCl_3$) δ 26.15, 28.20, 54.23 (d, 5.86 Hz), 68.77 (d, 7.33 Hz), 80.21, 120.02 (d, 4.39 Hz), 125.55, 129.82, 150.21 (d, 7.33 Hz), 155.38, 169.01; ^{31}P NMR ($CDCl_3$) δ −12.05; FAB mass spectrum (Ar, positive mode), *m/z* (rel intensity) 473 (0.7, M + Na^+), 451 (5, MH^+), 395 (10), 351 (10), 251 (43), 175 (9), 145 (22), 127 (12), 101 (100).

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Boc-Ser$_1$(PO_3Ph_2)-Ser$_2$(PO_3Ph_2)-NHMe (4). *N*-Methylmorpholine (0.59 g, 5.88 mmol) in THF (2 mL) and isobutyl chloroformate (0.745 g, 5.46 mmol) in THF (2 mL) were successively added to a solution of Boc-Ser(PO_3Ph_2)-OH (2.57 g, 5.88 mmol) in THF (10 mL) at −20 °C. After an activation period of 3 min, a solution of peptide **3** (1.62 g, 4.20 mmol) and *N*-methylmorpholine (0.424 g, 4.20 mmol) in THF (5 mL) was added to the solution, and the resulting solution was stirred for 2 h at −20 °C prior to the addition of 5% $NaHCO_3$ (5 mL). After 30 min at 20 °C, dichloromethane (100 mL) was added and the organic phase washed with 5% $NaHCO_3$ (2 × 30 mL) and 1 M HCl (2 × 30 mL), dried (Na_2SO_4), and filtered. Evaporation of the solvent under reduced pressure gave peptide **4** as a white crystalline solid (3.09 g, 96 %), mp 107–108 °C: $[\alpha]^{23}_D$ +0.47° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.41 (s, 9 H, Boc CH_3), 2.65 (d, 3 H, J_{NH-H} = 4.61 Hz, NHCH_3), 4.20–4.80 (m, 6 H, Ser$_{1,2}$ α-CH and β-CH_2), 5.73 (br d, 1 H, J_{NH-H} = 5.71 Hz, Ser$_1$ NH), 6.93 (br q, 1 H, J_{NH-H} = 5.49 Hz, NHCH$_3$), 7.10–7.80 (m, 20 H, Ar H), 7.60 (br d, 1 H, J_{NH-H} = 5.71 Hz, Ser$_2$ NH); ^{13}C NMR ($CDCl_3$) δ 26.22, 28.07, 53.44 (d, 6.10 Hz), 55.31 (d, 7.33 Hz), 67.91 (d, 6.10 Hz), 68.15 (d, 6.10 Hz), 80.75, 119.94 (d, 4.89 Hz), 125.59, 129.83, 150.06 (d, 7.32 Hz), 155.66, 167.75, 168.62; ^{31}P NMR ($CDCl_3$) δ −11.23, −11.44; FAB mass spectrum (Ar, positive mode), *m/z* (rel intensity) 792 (0.1, M + Na^+), 770 (1, MH^+), 671 (5), 464 (6), 420 (3), 292 (18), 251 (65), 214 (54), 196 (22), 170 (100), 154 (16), 110 (18), 101 (18).

Boc-Ser$_1$(PO_3Ph_2)-Ser$_2$(PO_3Ph_2)-Ser$_3$(PO_3Ph_2)-NHMe (6). *N*-Methylmorpholine (0.325 g, 3.22 mmol) in THF (2 mL) and isobutyl chloroformate (0.41 g, 3.00 mmol) in THF (2 mL) were successively added to a solution of Boc-Ser(PO_3Ph_2)-OH (1.41 g, 3.22 mmol) in THF (10 mL) at −20 °C. After an activation period of 3 min, a solution of dipeptide **5** (1.62 g, 2.30 mmol) and *N*-methylmorpholine (0.232 g, 2.30 mmol) in THF (5 mL) was added to the solution, and the resulting solution was stirred for 2 h at −20 °C prior to the addition of 5% $NaHCO_3$ (3 mL). After 30 min at 20 °C, dichloromethane (100 mL) was added and the organic phase washed with 5% $NaHCO_3$ (2 × 30 mL) and 1 M HCl (2 × 30 mL), dried (Na_2SO_4), and filtered. Evaporation of the solvent under reduced pressure gave tripeptide **6** as a clear oil (2.46 g, 98%): $[\alpha]^{23}_D$ +0.71° (*c* 1, $CHCl_3$); ^1H NMR ($CDCl_3$) δ 1.43 (s, 9 H, Boc CH_3), 2.51 (d, 3 H, J_{NH-H} = 4.61 Hz, NHCH_3), 4.10–5.00 (m, 9 H, Ser$_{1,2,3}$ α-CH and β-CH_2), 5.61 (br d, 1 H, J_{NH-H} = 5.71 Hz, Ser$_1$ NH), 6.91 (br q, 1 H, J_{NH-H} = 8.13 Hz, NHCH$_3$), 7.10–7.80 (m, 30 H, Ar H), 8.04 and 8.13 (each br d, 1 H, J_{NH-H} = 7.44 and 8.57 Hz, Ser$_2$ and Ser$_3$ NH); ^{13}C NMR ($CDCl_3$) δ 25.90, 28.05, 53.86 (d, 7.69 Hz), 54.04 (d, 4.39 Hz), 54.62 (d, 6.59 Hz), 67.34 (d, 6.59 Hz), 67.97 (d, 6.59 Hz), 68.27 (d, 6.59 Hz), 119.83 (d, 5.49 Hz), 125.46, 129.66, 149.99 (d, 6.60 Hz), 154.96, 167.64, 167.74, 168.76; ^{31}P NMR ($CDCl_3$) δ −11.10, −11.25, −11.49; FAB mass spectrum (Ar, positive mode), *m/z* (rel intensity) 1111 (2, M + Na^+), 1089 (1, MH^+), 989 (5), 857 (2), 783 (2), 533 (8), 515 (5), 489 (24), 292 (38), 283 (73), 251 (100), 219 (41), 196 (12), 154 (38), 111 (35).

Hydrogenolytic Deprotection. General Procedure. A rapidly stirred solution of **2**, **4**, or **6** (0.4 mmol) in 50% TFA/AcOH containing 83% platinum oxide (1.1 mmol PtO_2 per mmol phenyl group) was charged with hydrogen at atmospheric pressure. On cessation of hydrogen uptake (~1–3 h), the platinum was removed by gravity filtration and the solvent removed by evaporation under reduced pressure. Repeated trituration of the residue with diethyl ether (3 × 30 mL) followed by high vacuum drying gave the *P*Ser peptide **7**, **8**, or **9** as light white flakes.

CF_3CO_2H·H-*P*Ser-NHMe (7) (0.120 g, 96%): $[\alpha]^{23}_D$ +0.36° (*c* 1, H_2O); ^{13}C NMR (D_2O) 25.98, 53.46 (d, 5.49 Hz), 63.14 (d, 4.40 Hz), 167.18; ^{31}P NMR (D_2O) −0.01; FAB mass spectrum (Ar, positive mode), *m/z* (rel intensity) 221 (25, M − H + Na^+), 199 (100, M^+), 167 (2), 140 (5), 110 (17), 101 (45, M^+ − 98).

CF_3CO_2H·H-*P*Ser-*P*Ser-NHMe (8) (0.184 g, 96%): $[\alpha]^{23}_D$ +0.04° (*c* 1, H_2O); ^{13}C NMR (D_2O) 26.3, 53.6 (d, 8.79 Hz), 54.9 (d, 5.12 Hz), 63.3 (d, 3.66 Hz), 64.3 (d, 3.66 Hz), 167.5, 170.9; ^{31}P NMR (D_2O) +0.15, −0.24; FAB mass spectrum (Ar, positive mode), *m/z* (rel intensity) 388 (2, M − H + Na^+), 366 (100, M^+), 268 (20, M^+ − 98), 170 (40, *m/z* 268 − 98), 140 (25).

CF_3CO_2H·H-*P*Ser-*P*Ser-*P*Ser-NHMe (9) (0.243 g, 94%): $[\alpha]^{23}_D$ −0.38° (*c* 1, H_2O); ^{13}C NMR (D_2O) δ 26.1, 53.5 (d, 7.69 Hz), 54.2 (d, 7.69 Hz), 54.7 (d, 7.69 Hz), 63.2 (d, 4.39 Hz), 64.1 (d, 4.39 Hz), 64.2 (d, 4.39 Hz), 167.1, 170.6 and 171.1; ^{31}P NMR (D_2O) δ +0.09, +0.09, and −0.15; FAB mass spectrum (Ar, positive mode), *m/z* (rel intensity) 555 (5, M − H + Na^+), 533 (7, M^+), 435 (3, M^+ − 98), 391 (2), 369 (2), 337 (5, *m/z* 435 − 98), 267 (6), 251 (10), 242 (12), 239 (10, *m/z* 337 − 98), 229 (7), 216 (10), 175 (32), 140 (20), 110 (100), 102 (88).

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Improved Synthesis of Alkynylphenyliodonium Arylsulfonates (RC≡CIPh•OSO_2Ar)

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Multicoordinate (hypervalent)iodine chemistry is undergoing a renaissance.[1] The latest member of the family of polyvalent iodine compounds, alkynylphenyliodonium arylsulfonates (**3**), has rapidly become a key reagent in numerous, novel transformations. Koser and co-workers[2] have employed **3** in the preparation of aryl(2-furyl)-iodonium tosylates that serve as microbicides.[3] We have used **3** as precursors to hitherto unknown, unique alkynyl sulfonate esters,[4] alkynyl phosphates,[5] and alkynyl carboxylates.[5,6] Moreover, **3** serves as a progenitor of a novel tricoordinate vinyliodinane species[7] and alkylidenecarbene–iodonium ylides.[7,8] Finally, the stereoselective formation of conjugated enynes via coupling of alkynyliodonium tosylates and vinylcopper reagents has been reported.[9]

To date the only known procedure for the preparation of these useful alkynylphenyliodonium arylsulfonates (**3**) involves the reaction of [hydroxy(tosyloxy)iodo]benzene[10] (**2**) with terminal acetylenes (**1**) as discovered by Koser[11] and elaborated by us,[4] as outlined in eq 1. However, this

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