was chromatographed on a 2.5 × 50 cm silica gel column using 3, 4, and 8% MeOH in $CHCl_3$ as eluant. Fractions were combined after TLC analysis to give 102 mg (4%) of **3′,4′-dimethyl-(+)-catechin (5)**: mp 247–8 °C (MeOH–$CHCl_3$); IR (KBr) 2.96, 6.67, 6.90, 8.04, 8.85, and 9.90 μm; MS *m/e* (rel intensity) 318 (39), 180 (100), 165 (18), 152 (20), 151 (35), 139 (38), and 43 (54); NMR (Me_2SO-d_6) δ 6.95 (3 H, b s, C_2′H, C_5′H, and C_6′H), 5.82 (2 H, b d, C_6H and C_8H), 4.58 (1 H, b d, C_2H), 3.75 (7 H, b s, OCH_3 and C_3H), and 2.50 (2 H, m, C_4H). Anal. Calcd for $C_{12}H_{18}O_6$: C, 64.14; H, 5.70. Found: C, 63.89; H, 5.88. In addition to starting material (780 mg, 39%), there was obtained a mixture of monomethyl catechins (857 mg, 43%) as an oil. Crystallization of the oil from MeOH–$CHCl_3$ gave 345 mg (17%) of white solid, mp 222–4 °C (recrystallized mp 228–30 °C). From the spectral data and its chemical reactions, this material was identified as 4′-methyl-(+)-catechin (**4**): IR (KRr) 2.98, 6.25, 6.65, 7.05, 8.04, 9.03, and 9.71 μm; MS *m/e* (rel intensity) 304 (50), 167 (17), 166 (100), 151 (13), 139 (82), 138 (25), and 137 (38); NMR (Me_2SO-d_6) δ 6.82 (3 H, b s, C_2′H, C_5′H, and C_6′H), 5.85 (2 H, b d, C_6H and C_8H), 4.55 (1 H, d, C_2H), 3.75 (4, H, b s, OCH_3 and C_3H), and 2.50 (2 H, m, C_4H). Anal. Calcd for $C_{16}H_{16}O_6$: C, 63.15; H, 5.30. Found: C, 62.48; H, 5.47.

3′,5,7-Triethyl-4′-methyl-(+)-catechin (6). A mixture of 200 mg of 4′-methyl-(+)-catechin (**4**) and 2.5 g of granular K_2CO_3 in 10 mL of acetone was heated to reflux, and 1.4 mL of diethyl sulfate was added in 0.2-mL aliquots through the condenser every 10 min. After the addition was completed, the reflux was continued overnight. The mixture was then filtered, and the precipitated was washed with 2 × 10 mL of acetone. Evaporation of the combined filtrate gave a liquid which solidified on stirring with 0.5% KOH solution overnight. Crystallization from EtOAc–hexane afforded 192 mg (75%) of **3′,5,7-triethyl-4′-methyl-(+)-catechin (6)**: mp 104–5 °C (recrystallized mp 108–9 °C); IR (KBr) 2.90, 6.34, 7.00, 7.25, 8.00, 8.78, 8.96, 9.80, and 12.6 μm; MS *m/e* (rel intensity) 388 (28), 196 (14), 195 (100), 194 (25), 167 (12), 166 (10), and 139 (11); NMR δ 6.96 (3 H, b s, C_2′H, C_5′H, and C_6′H), 6.12 (2 H, s, C_6H and C_8H), 4.60 (1 H, d, C_2H), 3.7–4.3 (10 H, m, OCH_2CH_3, OCH_2, and C_3H), 2.4–3.3 (2 H, m C_4H), 1.95 (1 H, m, OH), and 1.2–1.6 (9 H, m, OCH_2CH_3). Anal. Calcd for $C_{22}H_{28}O_6$: C, 68.02; H, 7.27. Found: C, 68.10; H, 7.16.

4′,5,7-Triethyl-3′-methyl-(+)-catechin (7). The oily mother liquors from the preparation of **5** (500 mg) were reacted in 20 mL of acetone with 2.8 mL of diethyl sulfate and 5 g of K_2CO_3 as described above. The crude product was crystallized from MeOH–H_2O to give 413 mg (2 crops, 65%) of **4′ 5,7-triethyl-3′-methyl-(+)-catechin (7)**: mp 118–120 °C (recrystallized from EtOAc–hexane mp 125–6 °C); IR (KBr) 2.94, 6.30, 7.00, 7.25, 7.94, 8.70, 9.00, 9.74, and 12.6 μm; MS *m/e* (rel intensity) 388 (34), 195 (100), 71 (37), 57 (59), 45 (38), 43 (46), and 41 (29); NMR δ 6.95 (3 H, b s, C_2′H, C_5′H, and C_6′H), 6.10 (2 H, s, C_6H and C_8H), 4.62 (1 H, d, C_2H), 3.7–4.3 (~10 H, m, OCH_2CH_3 and C_3H), 2.4–3.3 (2 H, m, C_4H), 2.10 (1 H, bs, OH), and 1.1–1.6 (9 H, m, OCH_2CH_3). Anal. Calcd for $C_{22}H_{28}O_6$: C, 68.02; H, 7.27. Found: C, 67.94; H, 7.47.

Permanganate Oxidation of 3′,5,7-Triethyl-4′-methyl-(+)-catechin (6).[10] A suspension of 200 mg of **6** in 10 mL of H_2O was heated to 100 °C with stirring, then 1.0 g of $KMnO_4$ were added in small portions over the course of 1 h. The solution was stirred at 100 °C for an additional hour then filtered hot. The MnO_2 was washed with 5 mL of hot 1% KOH solution, and the combined filtrates were cooled and acidified to pH 2 with concentrated HCl. Extraction with 2 × 10 mL of $CHCl_3$ followed by drying and evaporating the $CHCl_3$ gave a light yellow solid. Recrystallization from MeOH–H_2O afforded 13 mg of white solid, mp 159–162 °C. The solid was identical by MS comparison with an authentic sample of 3-ethoxy-4-methoxybenzoic acid (lit.[8] mp 163–4 °C, mmp 161–3.5 °C).

Permanganate Oxidation of 4′,5,7-Triethyl-3′-methyl-(+)-catechin (7). Ethylated catechin 7 was oxidized with 1 g of $KMnO_4$ at H_2O at 100 °C as described above. Recrystallization of the crude product from MeOH–H_2O gave 9 mg of white solid, mp 195–6 °C, identical by MS comparison with an authentic sample of 4-ethoxy-3-methoxybenzoic acid (lit.[9] mp 193–4 °C, mmp 195–6 °C).

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Registry No.—**1**, 154-23-4; **3**, 60383-97-3; **4**, 69912-75-0; **5**, 69912-76-1; **6**, 69912-77-2; **7**, 69912-78-3.

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Simple Preparations of *N*-(*tert*-Butyloxycarbonyl)-*O*-methyl-L-serine and *N*-(*tert*-Butyloxycarbonyl)-*O*-methyl-L-threonine by Direct Methylation

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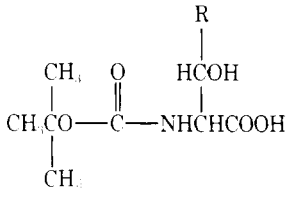
O-Methyl-L-serine[2] and *O*-methyl-L-threonine[3,4] are of interest for incorporating into peptides for structure–function relationship studies and in the search for useful analogues of biologically active molecules. *O*-Methyl-L-threonine is also an antagonist of isoleucine, inhibiting protein synthesis by ascites tumour cells.[5] The *N*-*tert*-butyloxycarbonyl (Boc) derivative of *O*-methyl-L-serine, which is useful for synthetic work, is best obtained by a five-step synthesis from L-serine of the *O*-methylamino acid, followed by acylation with *tert*-butyloxycarbonyl azide.[6] We describe in this paper a method of preparing *N*-(*tert*-butyloxycarbonyl)-*O*-methyl-L-serine (**2a**) in one step from *N*-(*tert*-butyloxycarbonyl)-L-serine (**1a**). Since the Boc group can be removed readily,[6] this provides the simplest access to the free *O*-methylamino acid as well. An analogous preparation of crystalline *N*-(*tert*-butyloxycarbonyl)-*O*-methyl-L-threonine (**2b**) is also described. Inefficient preparations of the latter[4] and the benzyloxycarbonyl derivative[3] using silver oxide and methyl iodide as reagents have been reported.



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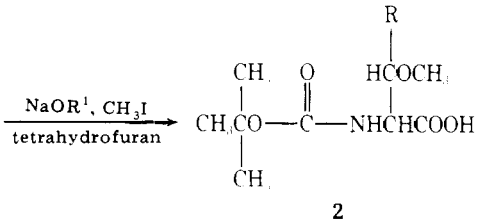

2

a, R = H; R^1 = CH_3
b, R = CH_3; R^1 = $CH(CH_3)_2$

Further to our studies on the N-methylation of *N*-(benzyloxycarbonyl)-[7] and *N*-(butyloxycarbonyl)amino acids[8] using methyl iodide and sodium hydride in tetrahydrofuran, the methylation of the O-unprotected derivatives of serine and threonine was examined.[9] The reaction proved complex due to partial selectivity and decomposition. We have now found that by using a sodium alkoxide as base, methylation of the butyloxycarbonyl derivatives takes place exclusively at the hydroxyl group without any decomposition occurring. The alkylation is incomplete; however, the products (**2**) can be

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readily isolated pure simply by extracting them from an aqueous solution into dichloromethane. The starting materials (1) remain completely in the aqueous phase. In this manner, *N*-(*tert*-butyloxycarbonyl)-*O*-methyl-L-serine (**2a**) was obtained as an oil in 45–55% yield from *N*-(*tert*-butyloxycarbonyl)-L-serine (**1a**) using sodium methoxide, and crystalline *N*-*tert*-butyloxycarbonyl)-*O*-methyl-L-threonine (**2b**) was obtained from *N*-(*tert*-butyloxycarbonyl)-L-threonine (**1b**) in 52% yield using sodium isopropoxide. Starting material is recoverable in 30–40% yields. The products contained no detectible amounts of starting material or N-methylated products (amino acid analysis, thin-layer chromatography, NMR), and they were shown to be stereochemically pure (<0.1% D isomer) by conversion to the C-terminal lysyl dipeptides followed by analysis for the diastereomeric dipeptides.[10] The corresponding *N*-benzyloxycarbonyl derivatives could not be obtained readily by the same procedure due to partial decomposition of starting materials and/or lack of selectivity.

Experimental Section

N-(*tert*-butyloxycarbonyl)-L-serine and -L-threonine were purchased from Chemical Dynamics Corp., Plainfield, N.J. The course of the methylations was monitored by 60-MHz ^{1}H NMR spectroscopy in $CDCl_3$ making use of the intensities of the following peaks (δ in ppm relative to Me_4Si): $OC(CH_3)_3$, 1.5; NCH_3, 2.9; OCH_3, 3.4.

***N*-(*tert*-Butyloxycarbonyl)-*O*-methyl-L-serine (2a).** *N*-(*tert*-butyloxycarbonyl)-L-serine (**1a**; 2.05 g, 10 mmol) was dissolved in 100 mL of tetrahydrofuran (distilled over $LiAlH_4$). To this was added 40 mL of sodium methoxide solution (freshly prepared by mixing 2 g of a 50% NaH dispersion in oil (40 mmol), 6 mL of methanol, and 74 mL of THF), and the mixture was shaken for 1 h. Methyl iodide (1 mL) in 10 mL of THF was added, and the mixture was shaken for 1 h. The remainder of the $NaOCH_3$ solution and 2 mL of CH_3I in 10 mL of THF were added, and the mixture was shaken for 18 h. The solvent was removed with a rotary evaporator, the residue was dissolved in 50 mL of water, and the solution was washed with ether and acidified at 0 °C with solid citric acid. The mixture was extracted with ethyl acetate, and the extract was washed with dilute aqueous $Na_2S_2O_3$ and saturated salt solution, dried (Na_2SO_4), and concentrated to an oil. The oil contains *N*-(*tert*-butyloxycarbonyl)-*O*-methyl-L-serine and *N*-(*tert*-butyloxycarbonyl)-L-serine in a 3:2 ratio. The mixture was dissolved in water (30 mL), and the desired product was taken out by extracting it into dichloromethane (1 × 30 mL). Evaporation of the dried solvent gave 1.17 g (55%) of *N*-(*tert*-butyloxycarbonyl)-*O*-methyl-L-serine as an oil, which gave a dicyclohexylammonium salt, crystallized from ethyl acetate–petroleum ether, with mp 115–117 °C and $[\alpha]_D^{23}$ +17.5° (*c* 2.0, methanol).

Anal. Calcd for $C_{21}H_{40}N_2O_5$: C, 63.00; H, 10.07; N, 7.00. Found: C, 62.90; H, 10.20; N, 6.89.

The remaining aqueous phase was saturated with NaCl and extracted with ethyl acetate. Evaporation of the solvent gave 0.68 g (30%) of a mixture containing *N*-(*tert*-butyloxycarbonyl)-L-serine and *N*-(*tert*-butyloxycarbonyl)-*O*-methyl-L-serine in a 5:1 ratio.

The results described above were obtained by carrying out all operations preceding the workup at 5 °C. The same results (45–50% yields) were obtained at 23 °C, or when using powdered $NaOCH_3$ in THF or powdered $NaOCH_3$ in THF (100 mL) containing 2% methanol as the methoxide solution.

***N*-(*tert*-Butyloxycarbonyl)-*O*-methyl-L-threonine (2b).** To a solution of sodium isopropoxide, prepared by mixing 0.40 g of an NaH dispersion in oil (8 mmol) and 2 mL of 2-propanol in 20 mL of purified THF, was added *N*-(*tert*-butyloxycarbonyl)-L-threonine (**1b**) (0.44 g, 2 mmol) and CH_3I (1 mL). The mixture was shaken at 5 °C for 20 h. Workup as described for the isolation of **2a** gave, after crystallization from $CHCl_3$, 0.24 g (52%) of *N*-(*tert*-butyloxycarbonyl)-*O*-methyl-L-threonine: mp 125–127 °C; $[\alpha]_D^{23}$ +7.0° (*c* 2.0, methanol), +2.6° (*c* 2.0, *N*,*N*-dimethylformamide) (lit.[4] oil). A 200-mg (40%) amount of *N*-(*tert*-butyloxycarbonyl)-L-threonine was recovered.

Anal. Calcd for $C_{10}H_{19}NO_5$: C, 51.49; H, 8.21; N, 6.01. Found: C, 51.38; H, 8.28; N, 5.94.

Optical Purities. **2a** and **2b** were coupled with the L and DL isomers of benzyl *N*$^{\alpha}$-(benzyloxycarbonyl)lysinate, and after removal of the protecting groups by catalytic hydrogenation separation of the diastereomeric dipeptides was performed on a 0.9 × 15 cm column of Aminex A-5 resin with a Beckman Model 120B amino acid analyzer using 0.35 N sodium citrate, pH 5.50, as eluting buffer.[10] The elution times (min) were as follows: L-Ser(Me)-L-Lys, 39; L-Ser(Me)-D-Lys, 45; L-Thr(Me)-L-Lys, 38; L-Thr(Me)-D-Lys, 45. The L–D isomers are the enantiomers of the D–L isomers. **2a** and **2b** contained less than 0.1% of the D isomer.

Note Added in Proof: The oily *N*-(*tert*-butyloxycarbonyl)-*O*-methyl-L-serine (**2a**) gradually crystallized after standing at −5 °C for several months. It can be recrystallized readily from chloroform–petroleum ether with the help of seed crystals and has mp 63–65 °C and $[\alpha]^{23}_D$ +6.8° (*c* 1.0, methanol).

Registry No.—**1a**, 3262-72-4; **1b**, 2592-18-9; **2a**, 51293-47-1; **2a** dicyclohexylammonium salt, 69912-63-6; **2b**, 48068-25-3.

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Photocyclization Reactions in Primary Amines. Convenient Synthesis of 1,4-Dihydrophenanthrene

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Photocyclization reactions have been widely investigated, and the synthetic and mechanistic aspects of this type of photoreaction have been amply reported.[1] For example, the photooxidative cyclization of stilbenes to phenanthrenes is a reaction of remarkable generality and synthetic utility for the preparation of various condensed aromatic hydrocarbons.[2] Although the chemical and physical aspects of the interactions of aromatic hydrocarbons with primary, secondary, and tertiary amines have been extensively studied and discussed,[3] the first study into the interactions between an amine (e.g., pyrrole, *N*-methylpyrrole) and an excited singlet stilbene molecule (which undergoes photocyclization) was reported by Kubota and Sakurai as recently as 1972.[4] More recently still, Lewis and Ho investigated the interactions between singlet *trans*-stilbene and several secondary and tertiary alkylamines in polar and nonpolar solvents.[5] In all cases it was shown that the photolytic reactions resulted in addition of the amine to the olefenic bond rather than cyclization.

Primary amines are known to be inefficient quenchers of arene fluorescent states, in contrast to secondary and tertiary amines with which even exciplex formation can be observed.[6] However the exact role of such compounds in the type of reactions under discussion here has not yet been studied in detail. We first reported[7] the reductive photocyclization of 2,3-diphenylbenzo[*b*]furan in primary amine solution, and recently Lapouyade and co-workers[8] observed that primary amines and diamines are efficient catalysts in the nonoxidative photocyclization reactions of several 1,1-diarylethylenes.

We wish to report here the photochemical behavior of *trans*-stilbene (**1a**) and various derivatives (**1b–d**) in propyl-

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