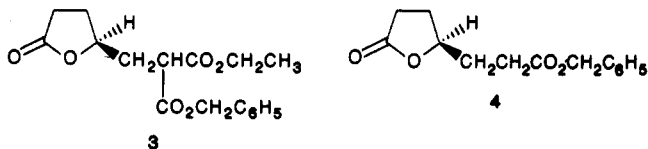


On the other hand, when **1b** is heated in water/ $\text{Me}_2\text{SO}$ /LiCl or in water/ $\text{Me}_2\text{SO}$  alone, **2** could readily be obtained in yields of 90% and 60%, respectively. Based on these observations, it can be concluded that the de-*tert*-butoxycarbonylation occurs more readily than the deethoxycarbonylation in water/ $\text{Me}_2\text{SO}$  in the absence of salts such as LiCl.

When di-*tert*-butyl malonate is refluxed in water/ $\text{Me}_2\text{SO}$ , *tert*-butyl acetate and *tert*-butyl alcohol are formed rapidly. The mixed malonate ester, *tert*-butyl ethyl malonate on heating in water/ $\text{Me}_2\text{SO}$  or water/ $\text{Me}_2\text{SO}$ /LiCl gives an ethyl acetate to *tert*-butyl acetate ratio of 10 and 6, respectively. Both reaction conditions lead to a selective de-*tert*-butoxycarbonylation.

One is tempted to conclude that the selective loss of the *tert*-butyl ester is based on an oxygen-alkyl cleavage of these esters to form a tertiary carbocation intermediate under the conditions of water/ $\text{Me}_2\text{SO}$ . The increased proportion of deethoxycarbonylation found in the water/ $\text{Me}_2\text{SO}$ /LiCl reaction is suggestive of more  $\text{S}_{\text{N}}2$  cleavage of the ethyl ester functionality which would lead to a higher proportion of *tert*-butyl acetate.

One case of a selective removal of an ester functionality from a mixed malonate ester has been reported recently.<sup>2</sup> The reaction of **3** (or its enantiomer) with water/ $\text{Me}_2\text{SO}$ /NaCl apparently leads only to **4** (90%), this product arising from selective attack of the carboxy functionality.



In addition an  $\alpha$ -cyano-*tert*-butyl ester has recently been reported as undergoing a de-*tert*-butoxycarbonylation on treatment with water/NaCl/ $\text{Me}_2\text{SO}$ .<sup>3</sup> It might be expected on the basis of the foregoing results that this could also be effectively accomplished by water/ $\text{Me}_2\text{SO}$  alone.

The results are of potential usefulness for the future construction of molecules of the activated types discussed here which will allow for the facile chemoselective removal of tertiary ester groups using only water in dipolar aprotic solvents.

## Experimental Section

**Preparation of 2.** (a) **From 1b, Water, and LiCl/ $\text{Me}_2\text{SO}$ .** A mixture of **1b**<sup>4</sup> (60.0 g, 0.227 mol),  $\text{Me}_2\text{SO}$  (300 mL), water (4.5 g, 0.25 mol), and LiCl (10.6 g, 0.25 mol) was heated at reflux for 5 h. The reaction mixture was cooled, water (200 mL) was added, and the mixture was extracted with methylene chloride (3  $\times$  150 mL). The extract was dried over  $\text{MgSO}_4$  and the solvent removed in vacuo. Distillation under reduced pressure removed *t*-BuOH and  $\text{Me}_2\text{SO}$ , and the dinitrile **2** was collected at 173–175 °C (0.5 mmHg) as a light yellow viscous oil (33.5 g, 90%).

(b) **From 1b and Water/ $\text{Me}_2\text{SO}$ .** A mixture of **1b** (6.0 g, 0.0227 mol),  $\text{Me}_2\text{SO}$  (30 mL), and water (0.45 g, 0.025 mol) was heated under reflux for 3 h. The workup and purification pro-

cedure was the same as in the procedure a above. Compound **2** was obtained (2.23 g, 60%).

(c) **From 1a and Water/ $\text{Me}_2\text{SO}$ .** A mixture of **1a**<sup>5</sup> (1.56 g, 0.0066 mol),  $\text{Me}_2\text{SO}$  (9 mL), and water (0.2 mL) was refluxed for 96 h. Workup and purification as in a above led to 0.09 g (8%) of **2**.

(d) **From 1a and Water/ $\text{Me}_2\text{SO}$ /LiCl.** A mixture of **1a** (53.64 g, 0.227 mol),  $\text{Me}_2\text{SO}$  (300 mL), water (4.5 g, 0.25 mol), and LiCl (10.6 g, 0.25 mol) was refluxed for 5 h. Workup and purification as in procedure a above gave **2** (21.50 g, 59%).

***tert*-Butyl Ethyl Malonate Reactions.** (a) **Water/ $\text{Me}_2\text{SO}$ /LiCl.** A mixture of *tert*-butyl ethyl malonate (2.0 g, 0.01 mol),  $\text{Me}_2\text{SO}$  (8 mL), water (0.21 g, 0.012 mol), and LiCl (0.5 g, 0.12 mol) was heated under reflux for 4 h. The reaction mixture was distilled at atmospheric pressure and the analysis of the distillate performed by proton NMR analysis to determine the product ratios. For this analysis the singlets at  $\delta$  2.02 ( $\text{CH}_3\text{CO}_2\text{Et}$ ), 1.95 ( $\text{CH}_3\text{CO}_2\text{-}t\text{-Bu}$ ), or 1.42 ( $\text{MeCO}_2\text{C}(\text{CH}_3)_3$ ) were used.

(b) **Water/ $\text{Me}_2\text{SO}$ .** Performed as above without LiCl.

## Nafion-H<sup>+</sup> Catalyzed De-*tert*-butylation of Aromatic Compounds<sup>1a</sup>

George A. Olah,\*<sup>1b</sup> G. K. Surya Prakash,<sup>1b</sup> Pradeep S. Iyer,<sup>1b</sup> Masashi Tashiro,\*<sup>1c</sup> and Takehiko Yamato<sup>1c</sup>

Donald P. and Katherine B. Loker Hydrocarbon Research Institute and Department of Chemistry, University of Southern California, University Park, Los Angeles, California 90089-1661, and Research Institute of Industrial Science and Department of Molecular Science and Technology, Graduate School of Engineering Science, Kyushu University, 6-1 Kasuga-kohen, Kasugashi, Fukuoka 816, Japan

Received September 16, 1986

It has been previously reported that the *tert*-butyl group could serve as a positional protective group for the preparation of some phenolic compounds,<sup>2-8</sup> diarylalkanes,<sup>9</sup> dibenzocycloheptadiene<sup>10</sup> 4-hydroxyphenyl aryl ether,<sup>11</sup> dimethyl- and dihydroxy[2.2]metacyclophanes,<sup>12-13</sup> 1,2-di- and 1,2,3-trisubstituted benzenes,<sup>14</sup> and 2-mono and 2,2-disubstituted biphenyls.<sup>15</sup>

The transalkylation (including trans *tert*-butylation) of aromatic compounds is usually carried in the liquid phase using sulfuric acid and Lewis acid halides, mainly  $\text{AlCl}_3$ , as catalyst. Although the conversions are high, generally complex workup procedures are necessary involving quenching of complexes (which often result in multistep workup procedures for Lewis acids like  $\text{AlCl}_3$ ,  $\text{AlBr}_3$ ,  $\text{BF}_3$ , etc.) or washing the products repeatedly for acid removal. Furthermore, *tert*-butyl-substituted aromatic compounds that contain hydroxyl, methoxy, carbonyl, and amino groups, etc., are easily complexed with Lewis acids. To obtain optimum yields in such cases, more than the molar equivalent of catalyst is required.

Over the years we have shown that Nafion-H,<sup>16</sup> a superacidic perfluororesinsulfonic acid is a convenient catalyst for a variety of acid-catalyzed synthetic transformations. The selectivity, high catalytic activity, and its ease of re-

(2) Pirillo, D.; Leggeri, P.; Vercesi, D.; Azzolina, O.; Traverso, G. *Farmaco, Ed. Sci.* 1985, 40, 623. We thank Dr. Traverso for calling our attention to this article.

(3) Roush, W. R.; Michaelides, M. R. *Tetrahedron Lett.* 1986, 27, 3353.

(4) Naslund, G.; Senning, A.; Lawesson, S. O. *Acta Chem. Scand.* 1962, 16, 1324.

(5) Zellars, G. R.; Levine, R. *J. Org. Chem.* 1948, 13, 911.

<sup>†</sup>Nafion-H is a registered trademark of Du Pont.

**Table I. Nafion-H Catalyzed Trans-*tert*-butylation of *tert*-Butyl 1,2-Di- and 1,2,3-Trisubstituted Benzenes**

run	substrate	acceptor <sup>a</sup>	time, h	product (%)	
				yield <sup>b</sup>	yield <sup>b</sup>
1	1a	toluene	12	2a (100)	3 (100)
2	1b	toluene	2	2b (100)	3 (100)
3	1c	toluene	2	2c (98)	3 (100)
4	1a	biphenyl	12	2a (80) <sup>c</sup>	
5	1b	biphenyl	6	2 (80) <sup>c</sup>	

<sup>a</sup> [Toluene]:1 = 20:1, [biphenyl]:1 = 5:1, catalyst 15 wt %.  
<sup>b</sup> Yields determined by GLC analysis. <sup>c</sup> Isolated yields shown.

generation frequently make Nafion-H the acid catalyst of choice. We report now that *tert*-butyl-substituted aromatic compounds are easily de-*tert*-butylated very efficiently to the corresponding aromatic compounds under Nafion-H catalysis in refluxing toluene solution.

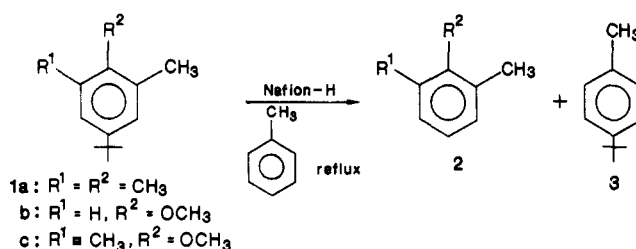
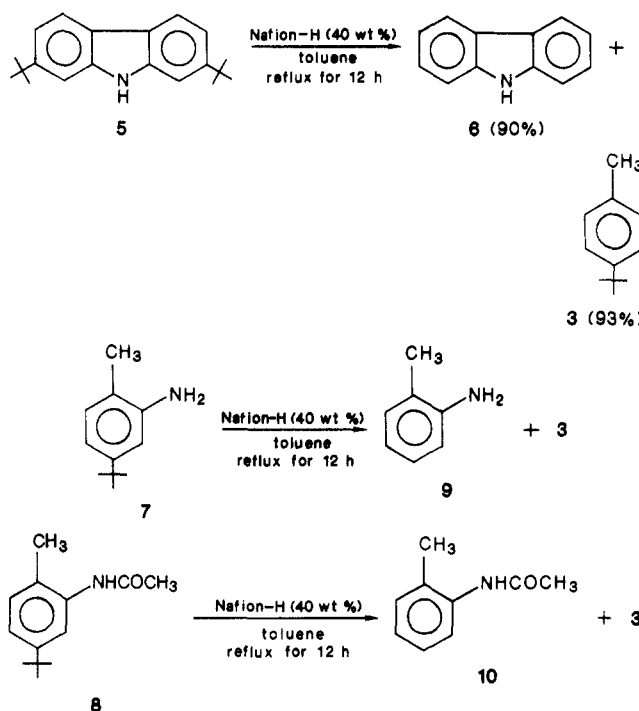
### Results and Discussion

The Nafion-H catalyzed de-*tert*-butylation of compounds 1a-c was carried out in refluxing toluene solution to afford the corresponding 1,2-di- and 1,2,3-trisubstituted benzenes 2a-c in almost quantitative yields (Table I; Scheme I). However, using toluene as the butyl acceptor the isolation of 2a-c from the reaction mixture by distillation was difficult since the boiling points of these compounds are almost the same as that of *tert*-butyltoluene (3). We previously reported a convenient method using biphenyl as an acceptor for the *tert*-butyl group in the Lewis acid catalyzed de-*tert*-butylation of some *tert*-butylbenzene derivatives, affording the desired 1,2-di- and 1,2,3-trisubstituted benzenes.<sup>17</sup>

As shown in runs 4 and 5 of Table I, during trans-*tert*-butylation using biphenyl in place of toluene as an acceptor, the desired 1,2-di- and 1,2,3-trisubstituted benzenes 2a,b could easily be isolated by distillation in good yields. The formation of 4-*tert*-butylbiphenyl (4) was determined only by GLC analysis without isolation.

The Nafion-H catalyzed trans-*tert*-butylation of *tert*-butyldiphenylalkanes was also carried out in refluxing toluene solution, and the results are summarized in the Table II.

With the exception of run 2 in Table II, the expected diphenyl, diphenylethanes, dibenzocycloheptadiene and 8,16-dimethyl[2.2]metacyclophane were obtained in good yields. However, in the case of diphenylmethane (run 2)

**Scheme I****Scheme II**

the desired product was not obtained since the trans-benylation competed with trans-*tert*-butylation. This result is similar to that of the Lewis acid catalyzed trans-*tert*-butylation of *tert*-butyldiphenylmethanes.<sup>18</sup>

The Nafion-H catalyzed trans-*tert*-butylation was further applied to substituted *tert*-butylphenols. The reaction was again carried out in refluxing toluene solution and the results are summarized in the Table III.

As shown in Table III the present method provides excellent yields, and no concomitant transbromination was observed under the reaction conditions (run 4). Moreover, only a catalytic amount of catalyst was needed instead of the usual stoichiometric quantity required for the conventional Lewis acid catalysts that bind to the hydroxyl group. The workup of the reaction mixture is extremely simple, involving filtration of the solid catalyst (which can be reused after simple regeneration), extracting the corresponding phenols into a solution of 10% NaOH and neutralizing the basic solution with acid.

It was also found that 2,7-di-*tert*-butylcarbazole (5) was easily de-*tert*-butylated to give carbazole (6) in 90% yield

(1) (a) Considered Catalysis by Solid Superacids. 21. Part 20: Olah, G. A.; Yamato, T.; Iyer, P. S.; Prakash, G. K. S. *J. Org. Chem.* 1986, 51, 2826. (b) University of Southern California. (c) Kyushu University.

(2) Tashiro, M.; Watanabe, H.; Tsuge, O. *Org. Prep. Proced. Int.* 1974, 6, 107.

(3) Tashiro, M.; Watanabe, H.; Tsuge, O. *Org. Prep. Proced. Int.* 1974, 6, 117.

(4) Tashiro, M.; Fukata, G.; Mataka, S.; Oe, K. *Org. Prep. Proced. Int.* 1975, 7, 231.

(5) Tashiro, M.; Watanabe, H.; Oe, K.; Tsuge, O. *Org. Prep. Proced. Int.* 1975, 7, 255.

(6) Tashiro, M.; Fukata, G. *Org. Prep. Proced. Int.* 1976, 8, 241.

(7) Tashiro, M.; Fukata, G.; Yamato, T.; Watanabe, H.; Oe, K.; Tsuge, O. *Org. Prep. Proced. Int.* 1976, 8, 249.

(8) Tashiro, M.; Fukata, G. *J. Org. Chem.* 1977, 42, 1208.

(9) Tashiro, M.; Yamato, T.; Fukata, G. *J. Org. Chem.* 1978, 43, 1413.

(10) Tashiro, M.; Yamato, T. *Synthesis* 1978, 214.

(11) Tashiro, M.; Yoshiya, H.; Yamato, T. *Synthesis* 1978, 399.

(12) Tashiro, M.; Yamato, T. *J. Org. Chem.* 1981, 46, 1543.

(13) Tashiro, M.; Koya, K.; Yamato, T. *J. Am. Chem. Soc.* 1982, 104, 3707.

(14) Tashiro, M.; Yamato, T. *J. Chem. Soc., Perkin Trans. 1* 1979, 176.

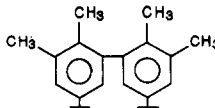
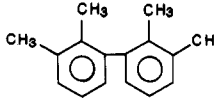
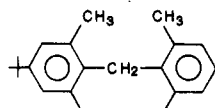
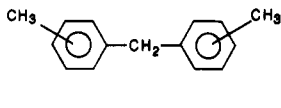
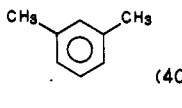
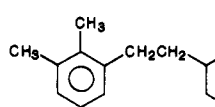
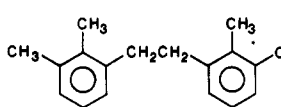
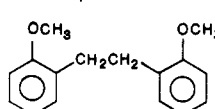
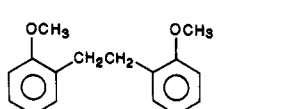
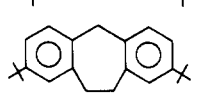
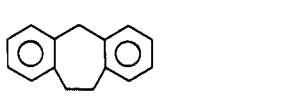
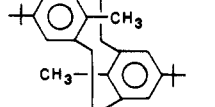
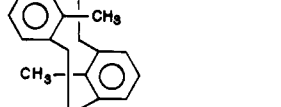
(15) Tashiro, M.; Yamato, T. *J. Org. Chem.* 1979, 44, 3037.

(16) Olah, G. A.; Iyer, P. S.; Prakash, G. K. S. *Synthesis* 1986, 513 and references therein.

(17) Brasen, W. R.; Hauser, C. R. *Organic Syntheses*; Wiley: New York, 1963; Collect. Vol. IV, p 508.

(18) Tashiro, M.; Yamato, T. *Synthesis* 1978, 435.

Table II. Nafion-H Catalyzed Trans-*tert*-butylation of *tert*-Butyldiphenylalkanes<sup>a</sup>

run	substrate	products <sup>b</sup>	yield, %	mp, °C		<i>tert</i> -butyl-toluene <sup>c</sup>
				found	ref	
1			83 <sup>d</sup>	114–115	114–115 <sup>15</sup>	91
2		 (70)  (40)				45
3			90 <sup>d</sup>	110–111	110–111 <sup>9</sup>	97
4			83 <sup>d</sup>	80–82	80–82 <sup>9</sup>	90
5			80 <sup>d</sup>	75–76	78–79 <sup>10</sup>	98
6			81 <sup>d</sup>	205–206	204–205 <sup>18</sup>	90

<sup>a</sup> Acceptor toluene; catalyst 15–40 wt %. Reaction carried out under reflux for 12 h. <sup>b</sup> Identity and purity (>98%) established by GLC (OV-1, 2 m, temperature 50–30 °C), IR, and <sup>1</sup>H NMR. <sup>c</sup> Yields determined by GLC analysis. <sup>d</sup> Isolated yields shown.

by the present method. However, attempts of the de-*tert*-butylation of 2-amino-4-*tert*-butyltoluene (7) and 2-(acetamino)-4-*tert*-butyltoluene (8) under various conditions failed, and we only recovered the starting compounds in quantitative yield (Scheme II).

The presently developed procedure offers advantages over previously reported methods. The present method provides excellent yields, easy workup and isolation of the products, and ready regeneration of the catalyst without loss of activity. Moreover, only a catalytic amount of Nafion-H is needed even for the de-*tert*-butylation of *tert*-butylphenols and *tert*-butylcarbazoles. As the *tert*-butyl group can serve as a convenient positional protective group in aromatic substitutions allowing high regioselectivity, its easy deprotection via Nafion-H catalysis should find wide applications.

### Experimental Section

*Tert*-butylated aromatics used in the current study were described and were available from our previous investigations. All other chemicals used were of highest purity available commercially. The Nafion-H catalyst was prepared from commercial (Du Pont) Nafion-K resin as previously described.<sup>16</sup> All melting points are uncorrected. NMR spectra were obtained on Varian Associates Model FT80 and Nippon Denshi JEOL FT-100 NMR spectrometers, respectively.

**General Procedure for the Trans-*tert*-butylation of *tert*-Butyl 1,2-Di- and 1,2,3-Trisubstituted Benzenes 1 in the Presence of Nafion-H Toluene as an Acceptor.** A mixture of *tert*-butyl 1,2-di- and 1,2,3-trisubstituted benzene 1 (8 mmol) and Nafion-H (15 wt %) in toluene (20 mL) was refluxed until completion of the reaction as monitored by GLC analysis (OV-1, 2 m). The solid resinsulfonic acid was then filtered off and the filtrate analyzed by GLC. The reaction condition and yields are summarized in Table I.

**Trans-*tert*-butylation of 1a and 1b in the Presence of Nafion-H Using Biphenyl as an Acceptor.** A mixture of 1a (8.9 g, 50 mmol), biphenyl (38.6 g, 250 mmol), and Nafion-H was stirred at 130–135 °C for 12 h. The reaction mixture was distilled under reduced pressure to afford 1,2,3-trimethylbenzene (2a): yield 4.86 g (80%); bp 95–100 °C (50 torr) (lit.<sup>17</sup> 176.1–176.2 °C).

Similarly, compound 2b was synthesized in the same manner as described above: yield 4.88 g (80%); bp 98–100 °C (30 torr) (lit.<sup>19</sup> 171–172 °C).

**General Procedure for the Trans-*tert*-butylation of *tert*-Butyldiphenylalkanes in the Presence of Nafion-H.** A mixture of *tert*-butyldiphenylalkanes (2 mmol) and Nafion-H (15–40 wt %) in toluene (10 mL) was refluxed until completion of the reaction as monitored by GLC analysis (OV-1, 2 m). The solid resinsulfonic acid was then filtered off and the filtrate distilled under reduced pressure to afford *p*-*tert*-butyltoluene. The residue was recrystallized from ethanol to give corresponding diphenylalkanes. The reaction conditions and the yields are summarized in Table II.

**General Procedure for the Trans-*tert*-butylation of *tert*-Butylphenols in the Presence of Nafion-H.** A mixture of *tert*-butylphenols (20 mmol) and Nafion-H in toluene (30 mL) was refluxed until completion of the reaction as monitored by GLC analysis (OV-1, 2 m). The solid resinsulfonic acid was then filtered and the filtrate washed with 10% sodium hydroxide and dried over sodium sulfate followed by distillation in reduced pressure to afford *tert*-butyltoluene.

After acidification of the sodium hydroxide extract with 10% HCl, the solution was extracted with ether, and ethereal extract dried over sodium sulfate, and ether evaporated to give corresponding phenols. The reaction conditions and the yields are summarized in Table III.

(19) Dictionary of Organic Compounds, 4th ed.; Oxford University: New York, 1978.

(20) Limpicht, H. *Ann.* 1981, 261, 332.

(21) Carrick, W. L.; Karapinka, G. L.; Kwiatowski, G. T. *J. Org. Chem.* 1969, 34, 2388.

Table III. Nafion-H Catalyzed Trans-*tert*-butylation of *tert*-Butylphenols<sup>a</sup>

run	substrate	reactn time, h	product <sup>b</sup>	yield, <sup>c</sup> %	mp or bp, °C (torr)		<i>tert</i> -butyl-toluene <sup>d</sup>
					found	ref	
1		2		96	90 (25)	182 <sup>19</sup>	96
2		2		96	90 (11)	202.5 <sup>19</sup>	94
3		2		91	104–106	105 <sup>19</sup>	97
4		8		80	95–97 (11)	194 <sup>19</sup>	83
5 <sup>e</sup>		2		98	110–111	109 <sup>20</sup>	98
6 <sup>e</sup>		2		97	274–275	272 <sup>21</sup>	98
7 <sup>e</sup>		12		86	223–228	223–228 <sup>13</sup>	97

<sup>a</sup> Reaction carried out under reflux; catalyst 5 wt %; toluene:phenols = 30:1. <sup>b</sup> Identity and purity (>98%) established by GLC (OV-1, 2 m, temperature 50–300 °C), IR, and <sup>1</sup>H NMR. <sup>c</sup> Isolated yields shown. <sup>d</sup> Yields determined by GLC analysis. <sup>e</sup> Catalyst 20 wt %.

**Trans-*tert*-butylation of 2,7-Di-*tert*-butylcarbazole (5) in the Presence of Nafion-H.** A mixture of 2,7-di-*tert*-butylcarbazole (5; 558 mg, 2 mmol) and Nafion-H (300 mg) in toluene (10 mL) was refluxed for 12 h. The solid resinsulfonic acid was then filtered and the filtrate treated as described above to give carbazole (6): yield 300 mg (90%); mp 244–245 °C (lit.<sup>22</sup> 245 °C).

(22) Cadogan, J. I. G.; Cumerson-wood, M.; Mackie, R. K.; Seavle, R. *J. G. J. Chem. Soc.* 1965, 4831.

**Regeneration of Nafion-H Catalyst.** The used catalyst was washed several times with acetone and deionized water, followed by drying at 105 °C for 10 h. The catalytic activity of regenerated catalyst was as good as that of fresh catalyst.

**Acknowledgment.** Support of the work at the University of Southern California by the National Institutes of Health is gratefully acknowledged.