1465 (s), 1350 (s), 1225 (s), 1050 (m), 1000 (m), 900 (s), 850 (s), 830 (s), 800 (s), 760 (s), 720 (s), 700 (s), 650 (s) cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.5–7.2 (m, 7), 3.3 (s, 3), 3.2 (s, 3).

***N,S*-Dimethyl-*S*-(1-naphthyl)sulfoximine (5f)**: mp 50–55 °C; IR 3200–2800 (s), 1750 (s), 1390 (s), 1240 (s), 1170 (m), 1100 (m), 1000 (m), 870 (m), 823 (s) cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.5–7.4 (m, 7), 3.2 (s, 3), 2.6 (s, 3). Anal. Calcd for $C_{12}H_{13}NOS$: C, 65.75; H, 5.94. Found: C, 65.42; H, 5.66.

***N*-(1-Phenylethyl)benzenesulfonimidoyl Fluoride (4g).** *N*-(1-Phenylethyl)benzenesulfinamide was obtained as a colorless oil which was a mixture of diastereomers (methyl doublets at δ 1.5 and 1.6) from benzenesulfinyl chloride and (–)-1-phenylethylamine (Aldrich). Oxidation of the sulfinamide mixture with chlorine and treatment of the crude sulfonimidoyl chlorides with sodium fluoride in acetonitrile gave **4g** (a mixture of diastereomers) as an oil: IR (film) 3050 (w), 2970 (w), 1450 (s), 1200 (s), 1100 (s), 750 (s) cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.2–7.0 (m, 10), 5.1 (m, 1), 1.8–1.5 (m, 3).

***S*-Methyl-*S*-phenyl-*N*-(1-phenylethyl)sulfoximines (5g).** The above fluoride was treated with methyllithium to give sulfoximines **5g** which could be separated by medium-pressure liquid chromatography on silica gel with hexane/EtOAc. The faster moving diastereomer, **diastereomer A**, was a colorless oil: bp 87–92 °C, (0.1 torr); IR (film) 3050 (m), 2950 (m), 1450 (s), 1250 (s), 1150 (s), 990 (s), 750 (s) cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.9–7.1 (m, 10), 4.2 (q, 1), 3.0 (s, 3), 1.5 (d, 3); $[\alpha]^{25}_D$ –14.2° (*c* 0.5, $CHCl_3$). Anal. Calcd for $C_{15}H_{17}NOS$: C, 69.52; H, 6.56. Found: C, 69.78; H, 6.84.

Diastereomer B: bp 93–95 °C (0.1 torr); IR similar to that of diastereomer A; ^1H NMR ($CDCl_3$) δ 8.2–7.2 (m, 10), 4.4 (q, 1), 3.0 (s, 3), 1.4 (d, 3); $[\alpha]^{25}_D$ –194.5° (*c* 0.7, $CHCl_3$).

***N*-(1-Naphthylethyl)-*S*-methyl-*S*-phenylsulfoximines (5h).** Optically pure (–)-1-naphthylethylamine (Norse) was treated sequentially with benzenesulfinyl chloride, *tert*-butyl hypochlorite, and tetrabutylammonium fluoride to yield **4h** which was treated with methyllithium to give **5h** as a mixture of diastereomers. The diastereomers were separated by medium-pressure liquid chromatography on silica gel with hexane/EtOAc. The faster eluting diastereomer, **diastereomer A**, was isolated as a white solid: mp 108–109 °C; $[\alpha]_D$ +81.6° (*c* 1.0, $CHCl_3$); IR 3400–3100, 2980 (s), 1585 (w), 1445 (s), 1250 (br), 1165 (br), 975 (s) cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.6 (m, 12), 5.1 (q, 1), 3.1 (s, 3), 1.7 (d, 3).

Diastereomer B was also a white solid: mp 88–89 °C; $[\alpha]_D$ –132.8° (*c* 1.0, $CHCl_3$); IR 3500–3150, 2995 (s), 2490 (w), 1615 (s), 1480 (s), 1465 (s), 1245 (br), 1185 (s), 1140 (s) cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.6 (m, 2), 5.2 (q, 1), 3.0 (s, 3), 1.6 (d, 3). Anal. Calcd for $C_{19}H_{19}NOS$: C, 72.73; H, 6.40. Found: C, 72.80; H, 6.26.

2-(*N*-Methylphenylsulfonimidoyl)-1-phenylethanone (7). Titanium tetrachloride (5 drops) was added to a stirred solution of *N*-methylbenzenesulfonimidoyl fluoride (173 mg, 1 mmol) and 1-phenyl-1-(trimethylsiloxy)ethene (212 mg, 1.1 mmol) in dichloromethane at –78 °C. After 30 min the reaction mixture was diluted with water and extracted with dichloromethane. The combined extracts were dried over sodium sulfate and reduced in vacuo. The residue was chromatographed (50% ether/hexane) to afford the sulfoximine (77%) identical chromatographically and spectroscopically with an authentic sample.[7]

***S*-(4-Methoxyphenyl)-*N*-methyl-*S*-phenylsulfoximine (6).** An excess of gaseous boron trifluoride was bubbled through a stirred solution of *N*-methylbenzenesulfonimidoyl fluoride (**4a**; 250 mg, 1.45 mmol) and anisole (56 mg, 1.45 mmol) in dichloromethane (10 mL) at 0 °C. After 15 min the reaction mixture was allowed to warm to room temperature before being diluted with dichloromethane (10 mL) and 2 M sodium hydroxide (10 mL). The organic phase was separated and the aqueous phase extracted with dichloromethane (3 × 10 mL). The combined organic phases were dried over sodium sulfate and concentrated to an oil which was chromatographed (ether/hexane) to yield sulfoximine (240 mg, 63%), which was chromatographically and spectroscopically identical with an authentic sample.[2]

2-(*N*-Methylphenylsulfonimidoyl)cyclohexanone (8). Titanium tetrachloride (0.5 mL, 4.54 mmol) was added dropwise to a stirred solution of *N*-methylbenzenesulfonimidoyl fluoride (**4a**; 500 mg, 2.9 mmol) and 1-(trimethylsiloxy)cyclohexene (600 mg, 3.53 mmol) in dichloromethane (25 mL) at –78 °C. After 15 min the reaction mixture was poured into saturated aqueous sodium hydrogen carbonate and extracted with dichloromethane. The combined extracts were dried over sodium sulfate and concentrated. The residue was chromatographed (hexane/ether) to afford the product: 370 mg (51%); mp 88–89 °C (needles from hexane–dichloromethane); IR ($CHCl_3$) 1715 (w), 1635 (s, C=C of enol form), 1250, 1095 cm^{-1}; ^1H NMR ($CDCl_3$) δ 8.0–7.2 (m, 5), 2.63 (s, 3), 2.56–1.13 (m, 8). Anal. Calcd for $C_{13}H_{17}NO_2S$: C, 62.15; H, 6.77. Found: C, 61.88; H, 6.77.

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Registry No. **1b**, 14934-02-2; **1c**, 14934-04-4; **1d**, 83706-17-6; **1e**, 14933-97-2; **1f**, 83706-18-7; **1g** (isomer 1), 83706-19-8; **1g** (isomer 2), 83706-20-1; **1h** (isomer 1), 83706-21-2; **1h** (isomer 2), 83706-22-3; **2a**, 15934-21-1; **2g** (isomer 1), 83706-23-4; **2g** (isomer 2), 83706-24-5; **2h** (isomer 1), 83706-25-6; **2h** (isomer 2), 83706-26-7; **4a**, 83706-27-8; **4b**, 83706-28-9; **4c**, 83706-29-0; **4d**, 83706-30-3; **4e**, 83706-31-4; **4f**, 83706-32-5; **4g** (isomer 1), 83706-33-6; **4g** (isomer 2), 83706-34-7; **4h** (isomer 1), 83706-35-8; **4h** (isomer 2), 83706-36-9; **5a**, 30004-67-2; **5b**, 56158-15-7; **5c**, 83706-37-0; **5d**, 83706-38-1; **5e**, 83706-39-2; **5f**, 83706-40-5; **5g** (isomer 1), 83706-41-6; **5g** (isomer 2), 83706-42-7; **5h** (isomer 1), 83706-43-8; **5h** (isomer 2), 83706-44-9; **5i**, 67087-36-9; **5j**, 54755-72-5; **6**, 69726-38-1; **7**, 83706-45-0; **8**, 83706-46-1; benzenesulfinyl chloride, 4972-29-6; 2-aminopyridine, 504-29-0; (–)-1-phenylethylamine, 2627-86-3; methyllithium, 917-54-4; (–)-1-naphthylethylamine, 10420-89-0; 1-phenyl-1-(trimethylsiloxy)ethene, 13735-81-4; anisole, 100-66-3; 1-(trimethylsiloxy)-cyclohexene, 6651-36-1; butyllithium, 109-72-8; phenyllithium, 591-51-5.

(7) Johnson, C. R.; Stark, C. J., Jr. *J. Org. Chem.* **1982**, *47*, 1196.

Translocative Rearrangements. Generality of the Formamidine-Induced Rearrangement of 4-Substituted 5-Amino-4-cyano-4*H*-imidazoles

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The generality of two different courses of cyclization reactions for 4-substituted 5-amino-4-cyano-4*H*-imidazoles (**5**) is demonstrated. One results from treatment of **5** with formamidine in a "translocative rearrangement" that leads to 8-substituted 4-aminoimidazo[1,5-*a*]-1,3,5-triazines (**7**). The other results from treatment with dimethyl acetylenedicarboxylate, without rearrangement, that leads to 8-substituted 8-cyano-8*H*-imidazo[1,5-*a*]pyrimidin-4-ones (**10**).

In the course of our investigation of rearrangement reactions best explained by the transient intermediacy of 5-substituted 5*H*-purines,[1-3] we discovered one reaction sequence in which the overall result is to remove a C≡N

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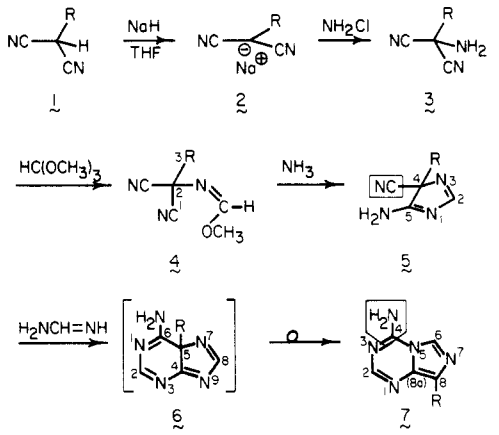
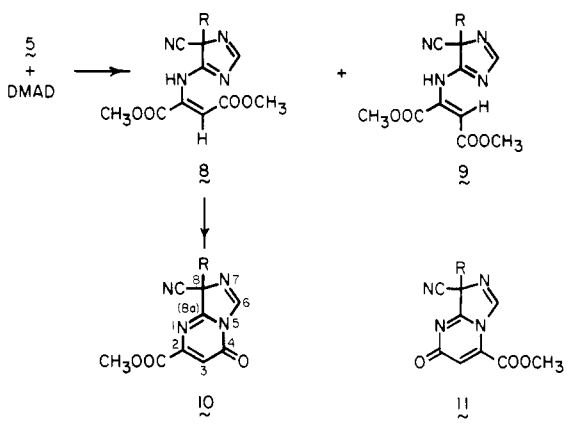
Scheme I



R: a, CH_3; b, C_2H_5; c, n-C_4H_9; d, $C_6H_5CH_2$; e, C_6H_5

Scheme II



R: b, C_2H_5; c, n-C_4H_9

group from the quaternary carbon of 5-amino-4-cyano-4-methyl-4*H*-imidazole and translocate it to a ring nitrogen two atoms removed, where it becomes attached as a $\geqslant CNH_2$ function.[4] In the present study, we show the generality of this "translocative rearrangement" of 4-substituted 5-amino-4-cyano-4*H*-imidazoles to 8-substituted 4-aminoimidazo[1,5-*a*]-1,3,5-triazines by mild treatment with formamidine at 20 °C.

The synthesis of 4-substituted 5-amino-4-cyano-4*H*-imidazoles (**5b–e**) closely parallels the method presented for the methyl derivative **5a**. Appropriately substituted malononitriles **1b**,[5,6] **1c**,[5] **1d**,[7,8] and **1e**[9] were prepared from the corresponding malonamide derivatives[10–13] by dehydration with phosphorus pentoxide. The preparation of the diamide derivatives from the readily available, corresponding diesters in methanolic ammonia at room temperature was facilitated by the addition of a small amount of sodium (~0.1 molar equiv).[14,15] The key intermediates were the substituted aminomalononitriles (**3**) that were obtained from **1** in yields of 68–79% by successive treatment with sodium hydride (Scheme I), to prepare the corresponding sodio derivatives, and an ethereal solution of monochloramine.[16] Since compounds of type **3** are unstable and darken in air within a few hours, they were either used directly in the next stage of synthesis or were stored as the stable, crystalline *p*-toluenesulfonate salts. The imidates **4**, prepared by the reaction of **3** with trimethyl orthoformate in the presence of a catalytic amount of formic acid (70–79% yield), could be stored for several days under adequate protection from moisture. Their ring closure to the desired 4-substituted 5-amino-4-cyano-4*H*-imidazoles (**5**) was effected in 2-propanol saturated with ammonia at 0–5 °C (62–78% yield). The fusion of the pyrimidine ring onto the imidazole ring in **5** by treatment with formamidine at room temperature yielded no isolable **6** (or its tautomers) but rather the translocative rearrangement product **7** in each case (55–73% yield).

Since we established the structure of 4-amino-8-methylimidazo[1,5-*a*]-1,3,5-triazine (**7a**) by independent and unequivocal synthesis,[4] the structural identity of the other 8-substituted 4-aminoimidazo[1,5-*a*]-1,3,5-triazines in the series (**7b–e**) followed from the analogous methodology and spectroscopic characteristics. A definitive monitor of the rearrangement of **5** to **7** in general was ^{13}C NMR spectroscopy, which indicated a quaternary carbon in the former and its absence in the latter. Specifically, the quaternary carbons for compounds represented by **5** appeared in the region δ 66–74, while the same carbons in the products **7**, identified by long-range ^{13}C–^{1}H coupling with the protons of the R group attached, had chemical shifts (δ 123–129) too large to have remained quaternary. Additionally, the ^{1}H NMR signals for the α protons were shifted downfield 0.5–0.8 ppm in products **7** compared with their precursors **5**. Partly on the basis of energetics, the intermediacy of a 5-substituted 5*H*-adenine (**6** or a tautomer) is favored in the conversion of **5** to **7**.[4] Whatever the detailed mechanistic pathway for the reaction of **5** with formamidine, the translocation of a C≡N function from C-4 in **5** to a ring nitrogen two atoms removed in **7** is both certain and general. A unique feature of this set of reactions 1 → **7** is that they are carried out at room temperature or below.

In the proton NMR spectra of the 4-substituted 5-amino-4-cyano-4*H*-imidazoles (**5**), the anisotropic effect of the ring was evident, for example, in the chemical shifts of the α-methylene protons at δ 1.8 and 2.2 in 5-amino-4-cyano-4-ethyl-4*H*-imidazole (**5b**). The diastereotopic protons were coupled with each other (J = 13.7 Hz) and with the methyl protons (J = 7.3 Hz), giving overlapping quartets of doublets. The α-methylene protons of the 4-butyl compound (**5c**) appeared as two multiplets centered at δ 1.7 and 2.2. In the case of R = benzyl (**5d**), the methylene protons appeared as doublets (J = 13.4 Hz) at δ 3.11 and 3.47.

Since the 4-substituted 5-amino-4-cyano-4*H*-imidazoles (**5**) represent a new structural type, additional chemistry aimed at constructing fused five- and six-membered-ring combinations is of interest. As an example, we treated a solution of **5b** in acetonitrile at room temperature with dimethyl acetylenedicarboxylate. The two products obtained, which had close chromatographic (TLC) mobilities in three different solvent systems, were separated by chromatography under pressure on a Woelm silica gel

(1) Golankiewicz, B.; Holtwick, J. B.; Holmes, B. N.; Duesler, E. N.; Leonard, N. J. *J. Org. Chem.* **1979**, *44*, 1740.
(2) Holtwick, J. B.; Golankiewicz, B.; Holmes, B. N.; Leonard, N. J. *J. Org. Chem.* **1979**, *44*, 3835.
(3) Holtwick, J. B.; Leonard, N. J. *J. Org. Chem.* **1981**, *46*, 3681.
(4) Hosmane, R. S.; Bakthavachalam, V.; Leonard, N. J. *J. Am. Chem. Soc.* **1982**, *104*, 235.
(5) Russell, P. B.; Hitchings, G. H. *J. Am. Chem. Soc.* **1952**, *74*, 3443.
(6) Hessler, J. C. *Am. J. Chem.* **1899**, *22*, 185.
(7) Hantzsch, A.; Osswald, G. *Chem. Ber.* **1899**, *32*, 649.
(8) Hessler, J. C. *Am. J. Chem.* **1899**, *22*, 180.
(9) Hessler, J. C. *Am. J. Chem.* **1904**, *32*, 123.
(10) Fischer, E.; Dilthey, A. *Chem. Ber.* **1902**, *35*, 849.
(11) Dox, A. W.; Yoder, L. *J. Am. Chem. Soc.* **1922**, *44*, 1578.
(12) Bischoff, H.; Siebert, H. *Justus Liebigs Ann. Chem.* **1887**, *239*, 96.
(13) Dox, A. W.; Yoder, L. *J. Am. Chem. Soc.* **1922**, *44*, 1564.
(14) Betts, R. L.; Hammett, L. P. *J. Am. Chem. Soc.* **1937**, *59*, 1568.
(15) Hammett, L. P. "Physical Organic Chemistry"; McGraw-Hill: New York, 1940; pp 356, 359.
(16) Coleman, G. H.; Johnson, H. L. *Inorg. Synth.* **1939**, *1*, 59.

column (32–63-μm particle size) by employing a mixture of chloroform and ethyl acetate (2:1) as the eluting solvent. The ^{1}H NMR spectrum of the first compound to be eluted (A) showed the presence of two distinct carbomethoxy groups with methyl proton resonances at δ 3.7 and 3.8, two CH singlets at δ 6.8 and 8.3, and an NH at δ 10.37, exchangeable with D_2O, in addition to the resonances for the ethyl group, overlapping quartets for the methylene (δ ~2.1), and a triplet for the methyl (δ 0.9, J = 7 Hz). The chemical shift and multiplicity for the methylene suggested that the parent ethyl group was still attached to a quaternary carbon in product A. Elemental microanalyses and the mass spectrum by fast atom bombardment (m/e 279, $M^+ + 1$) indicated the molecular formula to be $C_{12}H_{14}N_4O_4$. Theoretical structural possibilities were **8b** and **9b** and the corresponding imino diesters that might result from bond formation between N1 of **5b** and the dimethyl acetylenedicarboxylate (Scheme II).

The elemental analyses and FAB mass spectrum (m/e 247, $M^+ + 1$) of product B indicated a molecular formula of $C_{11}H_{10}N_4O_3$. The ^{1}H NMR spectrum of B revealed the presence of one methyl ester group, the absence of an exchangeable NH, the retention of the quaternary carbon to which the ethyl group was attached (two overlapping quartets for the methylene at δ 2.15), and two singlet CH's with resonances at δ 6.62 and 8.97. The infrared spectrum of product B showed two strong absorptions at ν_{max} 1750 and 1650 cm^{-1}, assignable to an ester and a lactam carbonyl, respectively. The assembled data were consistent with either bicyclic structure **10b** or **11b**.

An analysis of the ^{13}C NMR spectrum of the bicyclic product was deemed capable of distinguishing between structures **10b** and **11b** for B. Long-range ^{13}C–^{1}H coupling between the lactam carbonyl carbon and the CH of the five-membered ring should be readily detectable in **10b** (three bonds removed) but not in **11b** (five bonds removed). The ^{13}C NMR spectrum of product B revealed a total of eleven signals as expected. The identity of the carbon corresponding to each signal was determined by the chemical shift, multiplicity, and coupling constants. The quaternary carbon that appeared as a singlet at δ 69.7 in the uncoupled spectrum became a multiplet in the fully coupled spectrum due to spin–spin coupling with the adjacent diastereotopic methylene protons and the imidazole CH three bonds removed. The nitrile carbon at position 8 (see numbering in **10**) appeared at δ 114.5 as a doublet of doublets due to coupling with the diastereotopic methylene protons and failed to show coupling with the imidazole CH four bonds away, as expected. The two CH carbons, one on the imidazole and the other on the pyrimidine ring, were differentiated on the basis of chemical shifts, the lower field signal (δ 150.6, J = 230 Hz) being assigned to the imidazole carbon between nitrogens and the other (δ 112.4, J = 175.5 Hz) to the pyrimidinone carbon. The carbonyl carbons, which absorbed in the lowest field region, were differentiated on the basis of the predictable chemical shifts[17] and multiplicity. The singlet at lowest field (δ 168) was assigned to the ester carbonyl, while the other, a doublet of doublets at δ 166, was assigned to the lactam carbonyl carbon. The splitting was due to coupling with the two ring CH's two and three bonds removed.

Conclusive spectroscopic evidence was thus provided for methyl 8-cyano-8-ethyl-8*H*-imidazo[1,5-*a*]pyrimidin-4-one-2-carboxylate (**10b**) as the structure of product B from **5b**, and structural possibility **11b** could be discarded. The relationship of product A to product B was established by complete conversion of A to B upon heating in acetonitrile at reflux temperature for 4 h. Whether the diester precursor A was *Z* (**8b**) or *E* (**9b**) was a more subtle point. Under the reaction conditions of **5b** plus dimethyl acetylenedicarboxylate, i.e., acetonitrile solution at room temperature for 48 h, only one diester (A) was obtained along with **10b**. When product A alone was reintroduced to these identical conditions, it was not converted to **10b**. Heat was necessary to accomplish this, as described above. Accordingly, we were led to conclude that diesters **8b** and **9b** were formed initially, the *Z* diester was converted directly to **10b** at room temperature, and product A was the *E* diester (**9b**) that required thermal isomerization through **8b** in order to form **10b**. A similar pair of products, **9c** and **10c**, was obtained in the reaciton of the butyl derivative **5c** with dimethyl acetylenedicarboxylate, indicating generality.

In summary, we have demonstrated, as examples, two different courses for cyclization reactions starting with 4-substituted 5-amino-4-cyano-4*H*-imidazoles, one involving translocative rearrangement to 8-substituted 4-aminoimidazo[1,5-*a*]-1,3,5-triazines (**7**) and the other leading without rearrangement to 8-substituted 8-cyano-8*H*-imidazo[1,5-*a*]pyrimidin-4-one types (e.g., **10**).

Experimental Section

Melting points were determined on a Büchi capillary melting point apparatus and are uncorrected. ^{1}H nuclear magnetic resonance spectra were recorded on a Varian EM-390 or HR-220 spectrometer, operating at 90 and 220 MHz, respectively. ^{13}C NMR spectra were obtained on a JEOL FX-60, a WCV XLFT-100, or a Nicolet 360 fourier transform instrument, operating at 15.03, 25.2, and 90.5 MHz, respectively, and are reported in parts per million from tetramethylsilane. All NMR spectra were run in deuterated dimethyl sulfoxide unless otherwise specified. The electron impact (EI) mass spectra were run on a Varian MAT CH-5 low-resolution spectrometer with a 620i computer and a STATOS recorder. The fast atom bombardment (FAB) mass spectra were run on a Varian MAT 731 or 311A instrument. Microanalyses were performed by Mr. Josef Nemeth and his staff.

General Procedure for Alkyl- and Arylmalonamides. The solution of alkyl- or arylmalonic ester (0.11 mol) in methanol (100 mL) was added to a saturated solution of ammonia in methanol (200 mL) containing sodium (0.2 g) at 0 °C. The mixture was allowed to stand in a stoppered flask at room temperature for 2–3 days. The separated diamide was collected by filtration, washed with methanol, and recrystallized from the appropriate solvent. **Ethylmalonamide**: yield 93% (recrystallized from ethanol), mp 218 °C (lit.[10] mp 216 °C). ***n*-Butylmalonamide**: yield 88% [from ethanol–water (3:1)]; mp 199–200 °C (lit.[11] mp 200 °C). **Benzylmalonamide**: yield 99% (from ethanol); mp 222–223 °C (lit.[12] mp 224–226 °C). **Phenylmalonamide**: yield 97% (from ethanol); mp 232–233 °C (lit.[13] mp 233 °C).

General Procedure for Alkyl- and Arylmalononitriles (1). The malononitriles 1 were prepared by vacuum distillation of mixtures of the corresponding malonamides (0.07 mol) with phosphorus pentoxide (0.18 mol). The crude products were redistilled. **Ethylmalonitrile (1b)**: yield 82%; bp 100–102 °C (20 mmHg) [lit.[5] bp 90–91 °C (20 mmHg)]. ***n*-Butylmalononitrile (1c)**: yield 88%; bp 199–200 °C (20 mmHg) [lit.[5] bp 200 °C (20 mmHg)]. **Benzylmalononitrile (1d)**: yield 50%; mp 78–79 °C (lit.[7] mp 78–79 °C). **Phenylmalononitrile (1e)**: yield 71%; mp 68–69 °C (lit.[9] mp 68–69 °C).

General Procedure for the 2-Alkyl- and 2-Aryl-Substituted Aminomalononitriles and Their *p*-Toluenesulfonate Salts. In a dry three-necked flask fitted with a N_2 inlet, an addition funnel, and a reflux condenser was placed a slurry of NaH (prewashed three times with dry hexane to remove adhering oil; 1.86 g, 0.077 mol) in dry THF (45 mL). A solution of the corresponding malononitrile (0.07 mol) in 45 mL of dry THF was added slowly through the addition funnel, while the mixture was

(17) Levy, G. C.; Nelson, G. L. "Carbon-13 Nuclear Magnetic Resonance for Organic Chemists"; Wiley-Interscience: New York, 1972; pp 110–128.

stirred with a magnetic stirrer and cooled if necessary. Then, a cold, ethereal solution of chloramine[16] (0.08 mol) in 250 mL of ether was added through the top of the condenser. The mixture was stirred at ambient temperature overnight, and the yellowish precipitate was filtered. The filtrate was evaporated to dryness at 40–45 °C by using a rotary evaporator. Then, approximately 250 mL of dry ether was added to the residue, any precipitate formed was separated by filtration, and the filtrate was again evaporated to dryness, this time with drying over anhydrous Na_2SO_4, to obtain oily products that were used directly for the next stage in the reaction sequence.

The products were quite unstable and became dark within a few hours upon exposure to air. The stable, crystalline tosylate salts were prepared by adding *p*-toluenesulfonic acid monohydrate (5 mmol) to 5 mmol of crude aminomalononitriles in 8 mL of ether and stirring the mixture for 10 min at 20 °C with a magnetic stirrer. The precipitates were filtered in vacuo and recrystallized from acetonitrile as colorless crystals.

2-Amino-2-cyanobutyronitrile (3b) *p*-toluenesulfonate: mp 182–183 °C dec; ^{1}H NMR δ 1.18 (t, 3, CH_3), 2.08 (q, 2, CH_2), 2.38 (s, 3, aromatic CH_3), 6.42 (s, 3, NH_3, exchangeable with D_2O), 7.08 (d, 2, J = 8 Hz, aromatic CH's), 7.51 (d, 2, J = 8 Hz, aromatic CH's).

Anal. Calcd for $C_{12}H_{15}N_3O_3S$: C, 51.21; H, 5.33; N, 14.94. Found: C, 51.04; H, 5.30; N, 14.90.

2-Amino-2-benzylmalononitrile (3d) *p*-toluenesulfonate: mp 130–131 °C dec; ^{1}H NMR δ 2.29 (s, 2, CH_2), 2.51 (s, 3, CH_3), 7.08 (d, 2, J = 8 Hz, aromatic CH's), 7.46 (d, 2, J = 8 Hz, aromatic CH's), 5.51 (br, 3, NH_3, exchangeable with D_2O).

Anal. Calcd for $C_{17}H_{17}N_3O_3S$: C, 59.42; H, 4.95; N, 12.22. Found: C, 59.12; H, 5.09; N, 11.94.

α-Amino-α-cyanophenylacetonitrile (3e) *p*-toluenesulfonate: mp 139–140 °C dec; ^{1}H NMR δ 2.31 (s, 3, CH_3), 7.08 (d, 2, J = 8 Hz, aromatic CH's), 7.51 (d, 2, J = 8 Hz, aromatic CH's), 7.84 (s, 3, NH_3, exchangeable with D_2O), 7.3 (s, 5, phenyl).

Anal. Calcd for $C_{16}H_{15}N_3O_3S{\cdot}0.5H_2O$: C, 56.80; H, 4.73; N, 12.42. Found: C, 56.44; H, 4.72; N, 12.12.

General Procedure for 2-Alkyl- and 2-Aryl-2-[(methoxymethylene)amino]malononitriles (4). In a dry 200-mL, three-necked flask equipped with a magnetic stirrer, N_2 inlet, and a reflux condenser were placed the aminomalononitrle **3** (0.04 mol) and trimethyl orthoformate (80 mL, 0.73 mol). The mixture was stirred at room temperature under N_2 for 10 min. Then, formic acid (1.0 mL, 0.026 mol) was added through the top of the condenser, and the solution was refluxed for 3 h. The mixture was evaporated on a rotary evaporator by using a water bath at 40–45 °C. The residual oil was mixed with 5 mL of dry toluene, and the mixture was again evaporated. Distillation in a Kugelrohr apparatus afforded pure compounds.

2-Cyano-2-[(methoxymethylene)amino]butyronitrile (4b): yield 70%; bp 45–55 °C (0.1 mmHg); ^{1}H NMR ($CDCl_3$) δ 1.21 (t, 3, CH_2CH_3), 2.22 (q, 2, CH_2CH_3), 3.82 (s, 3, OCH_3), 7.99 (s, 1, CH); IR (neat) 3010 (=CH), 2950–2980 (CH_2, CH_3), 2100 (C≡N), 1650 cm^{-1} (C=N); mass spectrum (70 eV), m/e (relative intensity) 151 (M^+, 2), 124 (6), 122 ($M^+ - CH_3CH_2$, 46), 106 (17), 96 (100).

Anal. Calcd for $C_7H_9N_3O$: C, 55.62; H, 5.96; N, 27.81. Found: C, 55.27; H, 6.07; N, 28.60.

2-Cyano-2-[(methoxymethylene)amino]capronitrile (4c): yield 79%; bp 85–95 °C (0.2 mmHg); ^{1}H NMR ($CDCl_3$) δ 1.00 (t, 3, CH_3), 1.4–1.6 (m, 4, 2 CH_2), 2.11 (t, 2, CH_2), 3.81 (s, 3, OCH_3), 8.00 (s, 1, CH); IR (neat) 3015 (=CH), 2780–2960 (CH_3, CH_2), 2220 (C≡N), 1650 cm^{-1} (C=N); mass spectrum (70 eV), m/e (relative intensity) 180 ($M^+ + 1$, 2), 179 (M^+, 2), 164 ($M^+ - CH_3$, 8), 147 (20), 137 (15), 123 (100), 122 ($M^+ - C_4H_9$, 54), 111 (100).

Anal. Calcd for $C_9H_{13}N_3O$: C, 60.32; H, 7.32; N, 23.45. Found: C, 60.32; H, 7.39; N, 23.49.

2-Benzyl-2-[(methoxymethylene)amino]malononitrile (4d): yield 77%; bp 90–98 °C (0.11 mmHg); mp 29–30 °C; ^{1}H NMR ($CDCl_3$) δ 3.38 (s, 2, CH_2), 3.75 (s, 3, OCH_3), 7.25 (s, 5, phenyl), 7.71 (s, 1, CH); IR (neat) 3015 (=CH), 2950 (CH_2), 2250 (C≡N), 1650 cm^{-1} (C=N); mass spectrum (70 eV), m/e (relative intensity) 213 (M^+, 1), 155 (1), 128 (1), 91 (100).

Anal. Calcd for $C_{12}H_{11}N_3O$: C, 67.54; H, 5.15; N, 19.69. Found: C, 67.33; H, 5.26; N, 19.45.

α-Cyano-α-[(methoxymethylene)amino]phenylacetonitrile (4e): yield 77%; bp 85–90 °C (0.12 mmHg); ^{1}H NMR ($CDCl_3$) δ 3.81 (s, 3, OCH_3), 8.10 (s, 1, CH), 7.4–7.5 (s, 5, phenyl); IR (neat) 3020 (=CH), 2950 (CH_3), 2220 (C≡N), 1650 cm^{-1} (C=N); mass spectrum (70 e*V*) m/e (relative intensity) 199 (M^+, 49), 156 (18),141 (100), 129 (27), 122 (M^+ – Ph, 6), 114 (24).

Anal. Calcd for $C_{11}H_9N_3O$: C, 66.29; H, 4.52; N, 21.09. Found: C, 66.04; H, 4.28; N, 21.14.

General Procedure for 4-Alkyl- and 4-Aryl-Substituted 5-Amino-4-cyano-4*H*-imidazoles (5). A solution of **4** (3.3 mmol) in 2-propanol (27 mL) saturated at 0 °C with ammonia was stirred at 0–5 °C in a stoppered vessel for 24 h. After evaporation of the solvent, the residue was triturated with dry ether and the solid was filtered in vacuo. Pure compounds were obtained by passing the crude products through a silica gel column by using the appropriate eluting solvents listed below.

5-Amino-4-cyano-4-ethyl-4*H*-imidazole (5b): $CHCl_3$–acetone (1:1); yield 68%; mp >185 °C dec; ^{1}H NMR δ 0.91 (t, 3, CH_3), 1.8 (qd, 1, J = 13.7, 7.3 Hz, CH_aH_b), 2.2 (qd, 1, J = 13.7, 7.3 Hz, CH_aH_b), 7.3 (s, 1, CH), 8.59 (br, 2, NH_2, exchangeable with D_2O); ^{13}C NMR δ 7.81 (CH_3), 29.03 (CH_2), 70.72 (4), 117.3 (CN), 168.4 (2), 182.8 (5); IR (KBr) 3220 (NH), 2245 (C≡N), 1650 cm^{-1} (C=N); UV (ethanol) λ_{max} (pH 7) 270 nm (ϵ 5100), λ_{max} (pH 13) 283 (7530); mass spectrum (70 eV), m/e (relative intensity) 136 (M^+, 4), 121 (4), 109 (M^+ – HCN, 8), 108 (70), 94 (26), 80 (M^+ – CH_3CH_2 – HCN, 25).

Anal. Calcd for $C_6H_8N_4$: C, 52.94; H, 5.88; N, 41.17. Found: C, 52.96; H, 5.89; N, 41.15.

5-Amino-4-*n*-butyl-4-cyano-4*H*-imidazole (5c): $CHCl_3$–acetone (1:1); yield 62%; mp 190 °C dec; ^{1}H NMR δ 0.89 (t, 3, CH_3), 1.22–1.35 (m, 4, CH_2CH_2), 1.65–1.75 (m, 1, CH_aH_b), 2.12–2.25 (m, 1, CH_aH_b), 7.63 (s, 1, 2-H), 8.19 (br, 2, NH_2, exchangeable with D_2O); ^{13}C NMR δ 14.1 (CH_3), 21.6 (CH_2), 25.5 (CH_2), 35.2 (CH_2), 70.3 (4), 117.2 (CN), 170.7 (2), 183.1 (5); IR (KBr) 3220 (NH_2), 2880–2950 (CH_2, CH_3), 2250 (C≡N), 1660 cm^{-1} (C=N); UV (ethanol) λ_{max} (pH 7) 260 nm (ϵ 5460), λ_{max} (pH 13) 276 (11 470); mass spectrum (70 eV), m/e (relative intensity) 164 (M^+, 2), 109 (5), 108 (49), 96 (100), 81 (11), 80 (M^+– Bu – HCN, 10), 43 (38).

Anal. Calcd for $C_8H_{12}N_4$: C, 58.51; H, 7.36; N, 34.13. Found: C, 58.44; H, 7.41; N, 34.18.

5-Amino-4-benzyl-4-cyano-4*H*-imidazole (5d): $CHCl_3$–acetone (2:1); yield 72%; mp >210 °C dec; ^{1}H NMR δ 3.11 (d, 1, CH_aH_b), 3.47 (d, 1, CH_aH_b), 7.2–7.3 (m, 5, phenyl), 7.6 (s, 1, CH), 8.7 (br, 2, NH_2, exchangeable with D_2O); ^{13}C NMR δ 40.8 (CH_2), 70.9 (4), 116.9 (CN), 127.8, 130.2 (meta and ortho phenyl), 127.3 (para phenyl), 133.4 (iso phenyl), 170.5 (2), 182.5 (5); IR (KBr) 3200–3400 (NH), 2250 (C≡N), 1650 cm^{-1} (C=N); UV (ethanol) λ_{max} (pH 7) 274 nm (ϵ 2460), λ_{max} (pH 13) 286 (5900); mass spectrum (70 eV), m/e (relative intensity) 198 (M^+, 9), 155 (4), 128 (3), 104 (4), 91 (100).

Anal. Calcd for $C_{11}H_{10}N_4{\cdot}0.5H_2O$: C, 63.76; H, 5.27; N, 27.05. Found: C, 63.81; H, 5.02, N, 27.05.

5-Amino-4-cyano-4-phenyl-4*H*-imidazole (5e): $CHCl_3$–acetone (2:1); yield 78%; mp 195–196 °C dec; ^{1}H NMR δ 7.3–7.5 (m, 5, phenyl), 7.9 (s, 1, CH), 8.66 (br s, 1, NH, exchangeable with D_2O), 8.84 (br s, 1, NH, exchangeable with D_2O); ^{13}C NMR δ 73.9 (4), 116.2 (CN), 125.5 (ortho and meta phenyl), 132.7 (para phenyl), 145.3 (iso phenyl), 171.7 (2), 183.2 (5); IR (KBr) 3240 (NH), 2250 (C≡N), 1650 cm^{-1} (C=N); UV (ethanol) λ_{max} (pH 7) 268 nm (ϵ 5252), λ_{max} (pH 13) 288 (7100); mass spectrum (70 eV) m/e (relative intensity) 184 (M^+, 42), 157 (M^+ – HCN, 1), 142 (83), 115 (100), 88 (18).

Anal. Calcd for $C_{10}H_8N_4$: C, 65.21; H, 4.36; ; N, 30.43. Found: C, 65.21; H, 4.39; N, 30.62.

General Procedure for 8-Alkyl- and 8-Aryl-Substituted 4-Aminoimidazo[1,5-*a*]-1,3,5-triazines (7). A mixture of 4-substituted 5-amino-4-cyano-4*H*-imidazole **5** (1 mmol), formamidine acetate (1.3 mmol), and anhydrous methanol (15 mL) was stirred under N_2 at ambient temperature for 5 min to form a clear solution. A solution resulting from sodium (0.03 g, 1.3 mmol) dissolved in anhydrous methanol (7 mL) was introduced dropwise through a hypodermic syringe. The mixture was stirred overnight at room temperature. After evaporation to dryness, the residue was dissolved in 5 mL of methanol, the pH was adjusted to 6 with glacial acetic acid, and the mixture was chromatographed on a silica gel column with $CHCl_3$–acetone (1:1) as the eluting solvent. In the case of compound **7e**, the residue was dissolved in water (5 mL), the pH was adjusted to 6.5 with

glacial acetic acid, and the precipitate was recrystallized from ethyl acetate–benzene (4:1).

4-Amino-8-ethylimidazo[1,5-*a*]-1,3,5-triazine (7b): yield 61%; mp >232 °C dec; ^{1}H NMR δ 1.23 (t, 3, CH_2CH_3), 2.49 (q, 2, CH_2CH_3), 7.68 (s, 1, 2-H), 8.18 (br, 2, NH_2, exchangeable with D_2O), 8.21 (s, 1, 6-H); ^{13}C NMR δ 13.8 (CH_3), 19.1 (CH_2), 121.2 (2), 129.4 (8), 133 (8a), 148.3 (4), 149.3 (6); IR (KBr) 3000–3420 (NH), 2980 (CH_2CH_3), 1645 cm^{-1} (C=N); UV (ethanol) λ_{max} (pH 1) 309 nm (ϵ 5520), 274 (7090), λ_{max} (pH 7) 322 (4100), 271 (8660), λ_{max} (pH 13) 307 (8270), 286 (8820); mass spectrum (70 eV), *m/e* (relative intensity) 163 (M^+, 38), 148 ($M^+ - CH_3$, 100), 136 ($M^+ - HCN$, 1), 121 ($M^+ - HCN - CH_3$, 13), 106 (8), 43.2 (56).

Anal. Calcd for $C_7H_9N_5$: C, 51.52; H, 5.56; N, 42.90. Found: C, 51.52; H, 5.57; N, 42.77.

4-Amino-8-*n*-butylimidazo[1,5-*a*]-1,3,5-triazine (7c): yield 64%; mp >215 °C dec; ^{1}H NMR δ 0.96 (t, 3, CH_3), 1.40 (m, 2, CH_2), 1.71 (m, 2, CH_2), 2.75 (t, 2, CH_2), 7.73 (s, 1, 2-H), 8.35 (s, 1, 6-H), 8.39 (br, 2, NH_2, exchangeable with D_2O); ^{13}C NMR δ 13.6 (CH_3), 21.7 (CH_2), 25.3 (CH_2), 31.1 (CH_2), 121.2 (2), 128.4 (8), 133.5 (8a), 149.3 (6); IR (KBr) 3050–3450 (br, NH), 2920–2960 (CH_3, CH_2), 1650 cm^{-1} (C=N); UV (ethanol) λ_{max} (pH 1) 310 nm (ϵ 8070), 274 (12,420), λ_{max} (pH 7) 322 (15 380), 265 (4490), λ_{max} (pH 13) 310 (7050), 285 (8010); mass spectrum (70 eV), *m/e* (relative intensity) 191 (M^+, 15), 163 (5), 148 (100), 134 (M^+ - Bu, 2), 121 (11), 106 (6).

Anal. Calcd for $C_9H_{13}N_5$: C, 56.53; H, 6.85; N, 36.61. Found: C, 56.58; H, 6.69; N, 36.62.

4-Amino-8-benzylimidazo[1,5-*a*]-1,3,5-triazine (7d): yield 55%; mp >280 °C dec; ^{1}H NMR δ 4.07 (s, 1, CH_2), 7.22 (m, 5, phenyl), 7.78 (s, 1, 2-H), 8.29 (br, 2, NH_2, exchangeable with D_2O), 8.31 (s, 1, 6-H); ^{13}C NMR δ 31.8 (CH_2), 121.7 (2), 125.7 (para phenyl), 127.1 (8), 128.1, 128.4 (meta and ortho phenyl), 134.0 (8a), 140.7 (iso phenyl), 148 (4), 150 (6); IR (KBr) 2850–3400 (br, NH), 3030 (=CH), 2970 (CH_2), 1650 cm^{-1} (C=N); UV (ethanol) λ_{max} (pH 1) 302 nm (ϵ 5590), 270 (8230), λ_{max} (pH 7) 328 (5880), 271 (6760), λ_{max} (pH 13) 302 (8970), 269 (8240); mass spectrum (70 eV), *m/e* (relative intensity) 225 (M^+, 100), 198 ($M^+ - HCN$, 13), 197 (52), 182 (19), 155 (19), 148 (24), 128 (18).

Anal. Calcd for $C_{12}H_{11}N_5$: C, 63.98; H, 4.92; N, 31.09. Found: C, 63.75; H, 4.91; N, 31.25.

4-Amino-8-phenylimidazo[1,5-*a*]-1,3,5-triazine (7e): yield 73%; mp >260 °C dec; ^{1}H NMR δ 7.2–8.1 (m, 5, phenyl), 7.99 (s, 1, 2-H), 8.46 (s, 1, 6-H), 8.61 (s, 2, NH_2, exchangeable with D_2O); ^{13}C NMR δ 122.7 (2), 124.9 (meta phenyl), 125.4 (8), 125.8 (para phenyl), 128.3 (ortho phenyl), 134.0 (iso phenyl), 134.2 (8a), 148.7 (4), 151.6 (6); IR (KBr) 3180–3400 (br, NH), 3030 (=CH), 1650 cm^{-1} (C=N); UV (ethanol) λ_{max} (pH 1) 333 nm (ϵ 8560), 285 (11 630), 258 sh (ϵ 9920), λ_{max} (pH 7) 340 (8310), 295 sh (11 640), 284 (ϵ 13 000), λ_{max} (pH 13) 328 (17 110); mass spectrum (70 eV), *m/e* (relative intensity) 211 (M^+, 100), 184 (M^+– HCN, 8), 142 (29), 115 (34), 104 ($M^+ - HCN - Ph$, 12).

Anal. Calcd for $C_{11}H_9N_5$: C, 62.55; H, 4.30. Found: C, 62.72; H, 4.51.

4-Cyano-5-[(1,2-dicarbomethoxyvinyl)amino]-4-ethyl-4*H*-imidazole (Product A, 9b) and Methyl 8-Cyano-8-ethyl-8*H*-imidazo[1,5-*a*]pyrimidin-4-one-2-carboxylate (Product B, 10b). A mixture of 5-amino-4-cyano-4-ethyl-4*H*-imidazole (**5b**; 0.9 g, 6.62 mmol) and dimethyl acetylenedicarboxylate (1 g, 7.04 mmol) in dry acetonitrile (75 mL) was stirred under N_2 for 48 h. The clear red solution was mixed with 4 g of Woelm silica gel (32–63-μm particle size) and evaporated to dryness. The suspension of the residue in chloroform was loaded onto a column of the same silica gel (85 g) packed in chloroform and eluted first with $CHCl_3$ (500 mL), follwed by a mixture of $CHCl_3$–AcOEt (2:1, 1 L; flow rate 7 mL/min at 5 psi). Fractions of 10 mL each were collected.

Compound **9b** started coming off after about 400 mL of elution. The fractions were pooled and evaporated to yield **9b** as a yellow-orange oil: 0.8 g (43%); ^{1}H NMR δ 0.9 (t, J = 7.0 Hz, 3, CH_3 of C_2H_5), 2.1 (m, 2, two overlapping CH's of C_2H_5), 3.7 (s, 3, ester CH_3), 3.8 (s, 3, ester CH_3), 6.8 (s, 1, side-chain CH), 8.3 (s, 1, ring CH), 10.37 (br s, 1, NH, exchangeable with D_2O); IR (Nujol) 3275 (NH), 2250 (C≡N), 1750–1700 cm^{-1} (C=O); mass spectrum (FAB), *m/e* (relative intensity) 279 ($M^+ + 1$, 100), 247 ($M^+ + 1 - CH_3OH$, 27), 219 ($M^+ + 1 - OCH_3 - C_2H_5$, 20), 187 ($M^+ + 1 - 2CH_3OH - CO$, 12), 160 ($M^+ + 1 - CH_3OH - CO - CO_2CH_3$, 12.5).

Anal. Calcd for $C_{12}H_{14}N_4O_4$: C, 51.79; H, 5.07. Found: C, 51.80; H, 5.06.

Compound **10b** started coming off the column after about 500 mL of elution. The fractions were pooled and evaporated to obtain **10b** as a colorless solid: 550 mg (34%); mp 160–161 °C; ^{1}H NMR δ 1.1 (t, J = 7.0 Hz, 3, CH_3 of C_2H_5), 2.15 (m, 2, two overlapping CH's of C_2H_5), 3.9 (s, 3, ester CH_3), 6.62 (s, 1, 3-H), 8.97 (s, 1, 6-H); ^{13}C NMR δ 8.06 (CH_3 of C_2H_5), 30.74 (CH_2 of C_2H_5), 53.78 (ester CH_3), 69.70 (quaternary C), 112.39 (3), 114.49 (C≡N), 135.91 (2), 150.58 (6), 160.01 (8a), 166.04 (ring C=O), 168.25 (ester C=O); IR (KBr) 2200 (C≡N), 1750 (ester C=O), 1650 cm^{-1} (ring C=O); mass spectrum (FAB), *m/e* (relative intensity) 247 ($M^+ + 1$); mass spectrum (EI, 10 eV) 218 ($M^+ - C_2H_4$, 100), 186 ($M^+ - CH_3OH - CO$, 6), 160 ($M^+ + 1 - CO - CO_2CH_3$, 7).

Anal. Calcd for $C_{11}H_{10}N_4O_3$: C, 53.66; H, 4.09. Found: C, 53.39; H, 3.90.

Establishment of Relationship between Product A (9b) and Product B (10b). A solution of A (28 mg, 0.1 mmol) in acetonitrile (5 mL) was heated at reflux under N_2 for 4 h. The clear yellow solution was evaporated to dryness on a rotary evaporator to yield a glassy residue which was dissolved in benzene (1 mL) and reprecipitated with petroleum ether (bp 30–60 °C) to give a white crystalline solid: 21 mg (85%); mp 158–160 °C. A comparison of the TLC of this solid, in three different solvent systems, with that of the authentic sample of **10b** described above indicated identical R_f values.

4-*n*-Butyl-4-cyano-5-[(1,2-dicarbomethoxyvinyl)amino]-4*H*-imidazole (9c) and Methyl 8-*n*-Butyl-8-cyano-8*H*-imidazo[1,5-*a*]pyrimidin-4-one-2-carboxylate (10c). The procedure described for compounds **9b** and **10b** was employed.

Compound 9c: yield 48%; yellow-orange glass; ^{1}H NMR δ 0.9 (m, 3, CH_3 of butyl), 1.37 (m, 4, two center CH_2's of butyl), 2.03 (m, 2, α-CH_2 of butyl), 3.73 (s, 3, ester CH_3), 3.83 (s, 3, ester CH_3), 6.8 (s, 1, side-chain CH), 8.3 (s, 1, ring CH), 10.37 (br s, 1, NH exchangeable with D_2O); IR (neat) 3280 (NH), 2970 (*n*-C_4H_9), 2225 (C≡N), 1750 cm^{-1} (C=O); mass spectrum (10 eV), *m/e* (relative intensity) 306 (M^+, 2), 275 ($M^+ - OCH_3$, 8), 247 ($M^+ + 1 - CH_3OH - CO$, 100), 218 ($M^+ - OCH_3 - C_4H_9$, 5).

Anal. Calcd for $C_{14}H_{18}N_4O_4$: C, 54.89; H, 5.92. Found: C, 54.51; H, 5.90.

Compound 10c: yield 36%; colorless solid; mp 117–118 °C; ^{1}H NMR δ 0.97 (m, 3, CH_3 of butyl), 1.47 (m, 4, two center CH_2's of butyl), 2.1 (m, 2, α-CH_2 of butyl), 4.0 (s, 3, ester CH_3), 6.63 (s, 1, pyrimidine ring CH); IR (KBr) 2960 (butyl), 2250 (C≡N), 1750 (C=O), 1675–1650 cm^{-1} (C=O); mass spectrum (10 eV), *m/e* (relative intensity) 274 (M^+, 6), 218 ($M^+ + 1 - n$-C_4H_9, 100).

Anal. Calcd for $C_{13}H_{14}N_4O_3$: C, 56.93; H, 5.15; N, 20.43. Found: C, 56.89; H, 5.20; N, 20.34.

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Registry No. **1b**, 3696-37-5; **1c**, 7391-58-4; **1d**, 1867-37-4; **1e**, 3041-40-5; **3b**, 83845-18-5; **3b**·*p*-Ts, 83845-21-0; **3d**, 83845-19-6; **3d**·*p*-Ts, 83845-22-1; **3e**, 83845-20-9; **3e**·*p*-Ts, 83845-23-2; **4b**, 83845-24-3; **4c**, 83845-25-4; **4d**, 83845-26-5; **4e**, 83845-27-6; **5a**, 79680-96-9; **5b**, 83845-10-7; **5c**, 83845-11-8; **5d**, 83845-04-9; **5e**, 83845-05-0; **7a**, 79681-01-9; **7b**, 83845-06-1; **7c**, 83845-07-2; **7d**, 83845-08-3; **7e**, 83845-09-4; (*Z*)-**8b**, 83845-16-3; (*Z*)-**8c**, 83845-17-4; (*E*)-**9b**, 83845-14-1; (*E*)-**9c**, 83845-15-2; **10b**, 83845-12-9; **10c**, 83845-13-0; formamidine, 463-52-5; dimethyl acetylenedicarboxylate, 762-42-5; ethylmalonamide, 6082-49-1; *n*-butylmalonamide, 22085-89-8; benzylmalonamide, 1846-13-5; phenylmalonamide, 10255-95-5; trimethyl orthoformate, 149-73-5.