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Amino-Claisen Rearrangement. II. Quaternary Amino-Claisen Rearrangement of Anilinium Compounds with *ortho* Substituents

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Amino(N)-Claisen rearrangement of quaternary aniline derivatives with *ortho* substituents was investigated in relation to that of corresponding tertiary anilines. N-Allylated anilinium compounds **1** with a freely rotating *ortho* substituent such as a methyl or methoxy group yielded mostly the deallylated products **4** along with minor amounts of rearrangement products **2** and **3**. The corresponding tertiary anilines yielded *ortho* rearrangement products **6** together with *para* ones **7**. The quaternary N-Claisen rearangement of N-allylated 1,2,3,4-tetrahydroquinolinium salts **14** and indolinium salts **22** in which the *ortho* substituents are locked in rings afforded the *ortho* rearrangement products **15** and **23**, respectively in good yields. N-Claisen rearrangement of the corresponding aromatic tertiary amines **18** also took place in good yield. The above rearrangements could be rationalized on the basis of mechanistic considerations.

Keywords——quaternary amino-Claisen rearrangement; mechanism; [3,3] sigmatropic rearrangement; N-allyl-N,N-dimethyl-*o*-toluidinium bromide; N-allyl-N,N-dimethyl-*o*-anisidinium bromide; 1-allyl-1-methyl-1,2,3,4-tetrahydroquinolinium halides; 1-allyl-1,2-dimethylindolinium bromide; 8-allyl-1-methyl-1,2,3,4-tetrahydroquinoline; 6-allyl-1-methyl-1,2,3,4-tetrahydroquinoline; 7-allyl-1,2-dimethylindoline

In a previous report[1] we described a novel type of amino(N)-Claisen rearrangement[2] as shown in Chart 1. As a continuation of this work, we were interested in the effects of *ortho* substituents upon this quaternary N-Claisen rearrangement[3] and therefore prepared a series of *ortho*-substituted N-allylanilinium compounds. We have also synthesized the corresponding N-allylated tertiary anilines in order to compare the quaternary and tertiary N-Claisen rearrangements. In this article we describe the results of these rearrangements.

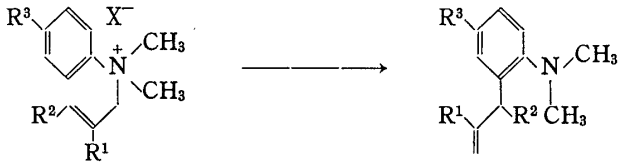

Chart 1

N-Claisen Rearrangements of Aniline Derivatives with Freely Rotating *ortho* Substituents

We first investigated N-allyl-*o*-toluidinium bromide **1a** and N-allyl-*o*-anisidinium bromide **1b**. These quaternary bromides **1** were prepared by treatment of the N,N-dimethyl compounds **4** with allyl bromide. Two principal reaction conditions (A and B)[1] were employed for the rearrangements of these quaternary salts **1**, and the results are summarized in Table I.

In contrast to the reaction of unsubstituted anilinium salts[1] the quaternary N-Claisen rearrangement of *ortho*-substituted anilinium compounds **1** gave the deallylated products **4** as major products and the rearranged products **2** and **3** as trace products. In reaction condition B, N-allylated-*o*-toluidinium bromide **1a** rearranged into the *ortho* rearrangement product **2a** (18%) more efficiently than N-allylated *o*-anisidinium bromide **1b** did into **2b**. In order to evaluate the effects of *ortho* substituents upon the quaternary N-Claisen rearrangement, the corresponding tertiary anilines **5** were prepared (see "Experimental") and the rearrangements of tertiary and quaternary anilines were compared. For the rearrangement of tertiary anilines,

TABLE I

Substrate	R.C.[a]	Products and yields (%)[b]			
		ortho	*para*	Deallylated	Others
1a	B	**2a** 18	**3a** 1	**4a** 25	**5a** 5
1b	A	**2b** 2	**3b** —	**4b** 22	**5b** 3
	B	**2b** 1	**3b** —	**4b** 41	**5b** 15
5a	C	**6a** 54(58)	**7a** 13(14)	**8a** 13(13)	
	D (23h)	**6a** 35(59)	**7a** 7(12)	**8a** <1	
5b	D (60h)	**6b** 65(79)	**7b** [c]	**8b** <1	
14a X=Cl	B	**15a** 79	**16** <1	**17a** 1	
X=Br	B	**15a** 95	**16** <1	**17a** 5	
X=I	B	**15a** 70	**16** <1	**17a** 22	
14b X=Br	B	**15b** 85	—	**17b** 3	
18a	C (180°)	**19a** 80	**20** 8	**21a** 1	
	D (8h)	**19a** 36*(77*)			
	hv/PhH	**19a** 4	**20** 31	**21a** 42	
18b	C	**19b** 57*			
22	B	**23** 88			

a) Reaction conditions: a solution of the quaternary salts (2 mmol) in glycerol-water (2/1) was heated at 140°C (bath temperature) for 2—4 h in the absence (A) or in the presence (B) of $NaHCO_3$ (2 mmol); amine and $BF_3 \cdot Et_2O$ (2 mol eq.) were heated at 140°C for 2—3 h (C); amine (2 mmol) in 2 N H_2SO_4 in glycerol-water (2/1, 6 ml) was refluxed at 140°C for the period indicated (D).

b) Yields are based on GLC analysis. Yields marked with *(asterisk) are isolated yields and the yields in parenthesis are corrected ones based on the consumed starting materials.

c) There were three unidentified products (4.9%, 4.5%, 2.2%) on GLC. For details of these products see "Experimental."

BF_3 etherate was employed as a catalyst for aprotic reaction (condition C)[4] and 2 N H_2SO_4 for protic reaction (D).[5] Tertiary aniline **5a** under reaction condition (C) provided an *ortho* rearrangement product **6a** (58%) and a *para* one **7a** (14%), along with the deallylated product **8a** (13%). Under reaction condition D the rearrangement was slow and tertiary anilines **5** yielded the *ortho* rearrangement product **6** after prolonged heating. Exclusive formation of the *ortho*-rearranged product **6b** was observed in the reaction of the *o*-anisidine derivative **5b** but some para rearrangement product **7a** (12%) was detected in the reaction of the *o*-toluidine derivative **5a**. Co-formation of the *para* rearrangement product is general when BF_3 etherate is used as a catalyst,[4] and *ortho* rearrangement is more exclusively observed in aqueous acid.[5]

The structures of the rearrangement products were characterized as shown in Charts 2 and 3. Secondary anilines **6** and **7a**, derived from the tertiary anilines **5**, were methylated by

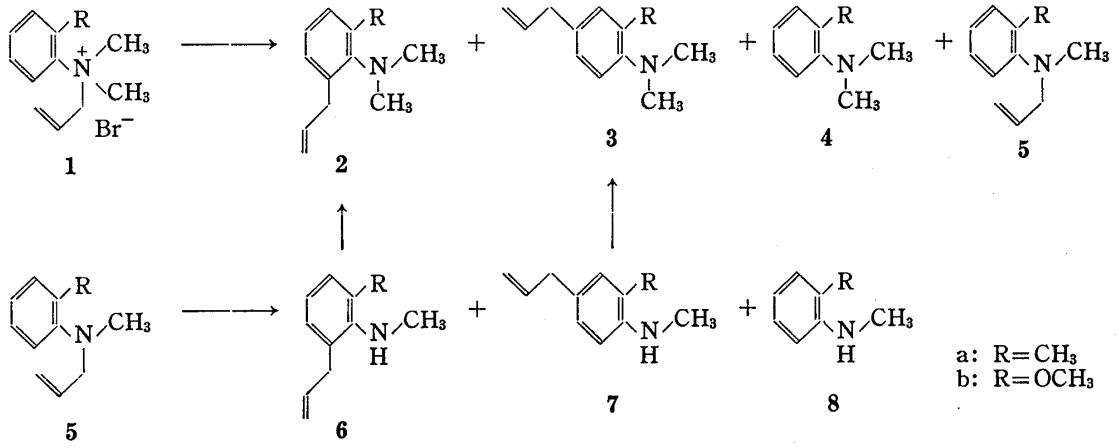

Chart 2

treatment with $HCHO–NaBH_3CN$[6] to provide **2** and **3a**. Product **2a** was identical with 3-allyl-2-dimethylaminotoluene that was prepared by Hofmann degradation of 1,1,8-trimethyltetrahydroquinolinium iodide **9a** in 7% yield. Product **2b** was derived into **11** which was identical with the specimen obtained from **9b** as shown in Chart 3. The structure of the *para* rearrangement product **3a** was deduced from mechanistic considerations and by spectral comparisons with **2a**. Although direct comparison of **3a** with an authentic specimen was not carried out, its isomer, 2-allyl-4-methyl-N,N-dimethylaniline **13**, was prepared by the quaternary N-Claisen rearrangement of N-allyl-N,N-dimethyl-*p*-toluidinium bromide **12** in order to eliminate the possibility of methyl migration during the rearrangement. The compounds **2a** and **13** were compared and proved to be non-identical by comparisons of their nuclear magnetic resonance (NMR) and in frared (IR) spectra and picrates.

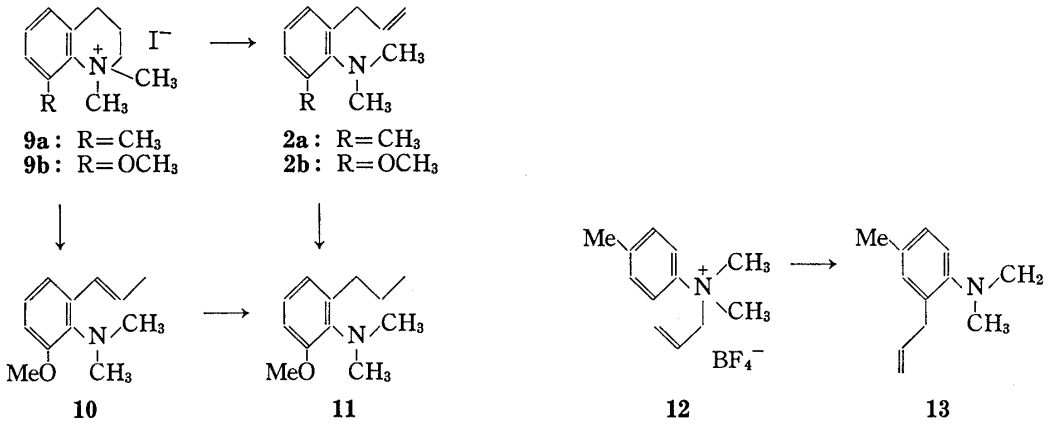

Chart 3

Possible reaction pathways for these rearrangements, based on the above results and the prvious report,[1] are listed in Chart 4. In quaternary N-Claisen rearrangement, the anilinium compounds **1a** and **1b** have steric interactions between the *ortho* substituent (R) and N-substituent (R′) in transition states I ($R'=CH_3$) and III ($R'=CH_3$). These steric interactions increase the energy requirement for the rearrangement. This additional energy requirement in relation to the unsubstituted counterparts is presumably the main reason why deallylation played a major role and the rearrangement yield was poor in quaternary N-Claisen rearrangement of *ortho*-substituted anilinium derivatives **1**. This *ortho* effect was more marked in

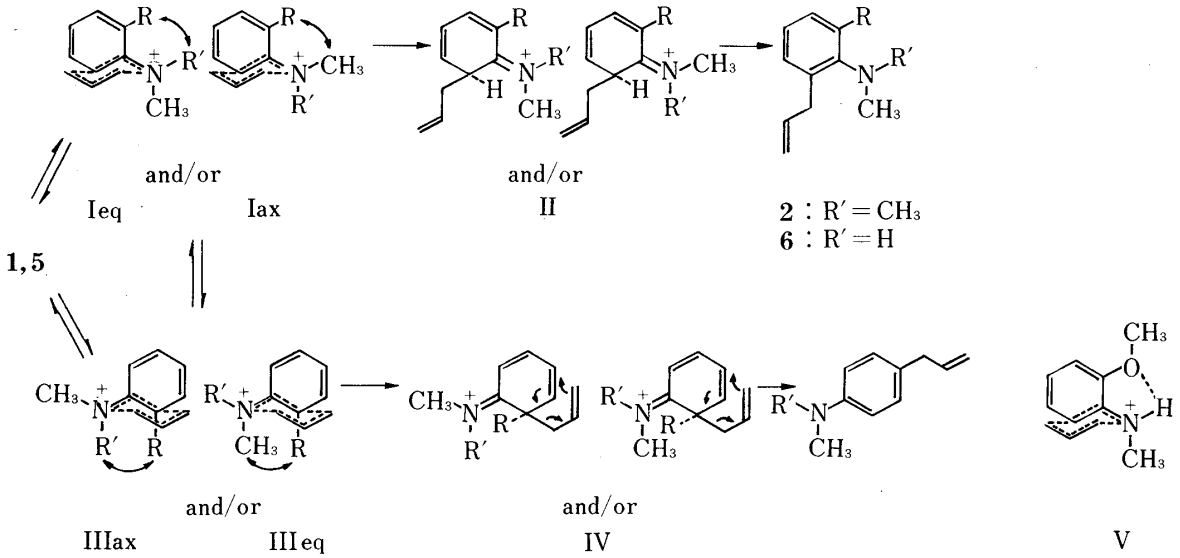

Chart 4

the methoxy-substituted aniline derivative **1b** than in the methyl-substituted one **1a**. Longer reaction time (12h) of **1b** under reaction condition B did not increase the yield of rearrangement product **2b** but did increase the yield of deallylated product **4b** (54%).

In contrast to the quaternary N-Claisen rearrangements of **1**, N-Claisen rearrangement of the corresponding tertiary anilines **5** resulted in different patterns of reaction. Under reaction condition D, as under the protic reaction conditions (A and B) for quaternary N-Claisen rearrangement, the tertiary aniline **5** rearranged into the secondary aniline **6** and **7** as major products. The formation of deallylated products **8** was negligible. In particular, the *o*-anisidine derivative **5b** yielded the *ortho* rearrangement product **6b** without any trace of the *para* rearrangement product **7b**, despite careful analysis of the reaction products. This specific *ortho* rearrangement could be attributed to the transition state V, a stabilized version of transition state Ieq (R=OCH_3, R'=H), in which the N-allyl group is directed to the unsubstituted *ortho* site by intramolecular hydrogen bonding. Care is necessary in considering the relative ease of tertiary N-Claisen rearrangement and quaternary N-Claisen rearrangement in the same series of compounds. Under protic condition (D), reversible association of a proton at the nitrogen atom of **5** may allow the transition states Ieq (R'=H) and IIIax (R'=H) to be the preferred ones for the rearrangements. In these transition states, the steric interactions between the *ortho* substituent R and N–H are smaller than those between R and N–CH_3 in transition states Iax (R'=H) and IIIeq (R'=H), so the energy requirements for the tertiary N-Claisen rearrangement of **5** might be much less than those for the conformational isomers Iax (R'=H) and IIIeq (R'=H), which are in virtually the same energy states as transition states I (R'=CH_3) and III (R'=CH_3) for quaternary N-Claisen rearrangement of **1**. These differences of energy requirements may allow the tertiary N-Claisen rearrangement to occur rather than the quaternary one. Since no *para* rearrangement product was observed in the quaternary N-Claisen rearrangement of simple anilinium compounds (R^3=H in Chart 1),[1] the quaternary N-Claisen rearrangement of **1a** might occur by an intramolecular [3, 3] sigmatropic mechanism, so that the ratio of *ortho* and *para* rearrangement products (**2a**/**3a**=18/1) would reflect the stabilities of the transition states I (R'=CH_3) and III (R'=CH_3); the steric interactions between *ortho* substituent (R=CH_3) and N–CH_3 would be more severe in III (R'=CH_3) (*quasi* 1,3-diaxial interaction) than in I (R'=CH_3) (*quasi peri* interaction). However, in tertiary N-Claisen rearrangement of **5** under protic condition (D) the difference of conformational stability between Ieq (R'=H) and IIIax (R'=H) might be lessened, thus shifting the product ratio in favor of *para* rearrangement (**6a**/**7a**=5/1). For *para* rearrangement the reaction pathway *via* transition states III and IV would play the major role in the reaction since the alternative route, the further rearrangement of the allyl group in transition state II, has to compete with the aromatization that could provide the driving force for *ortho* rearrangement. Under aprotic condition (C), the tertiary amine **5a** aslo rearranged into products **6a** (58%) and **7a** (14%), together with the deallylated product **8a** (13%). In this reaction BF_3 might associate with the tertiary nitrogen atom. This association of BF_3, which is bulkier than CH_3, might allow the transition states Iax (R'=BF_3) and IIIeq (R'=BF_3) to be preferred over their counterparts Ieq (R'=BF_3) and IIIax (R'=BF_3). Nevertheless, the poor nucleophilicity of the reagent as well as the aprotic condition would suppress the deallylation reaction and lead to major formation of rearrangement products. The ratio of *ortho* and *para* rearrangement products **6a**/**7a**=58/14 was comparable with that under reaction condition D (**6a**/**7a**=59/12). This similarity of ratio indicates that the energy difference between Iax (R'=BF_3) and IIIeq (R'=BF_3) is in the same range as that between Ieq (R'=H) and IIIax (R'=H), despite the association of the bulky BF_3 function.

The quaternary N-Claisen rearrangement of N-allylated anilinium compounds with freely rotating *ortho* substituents resulted in only minor formation of rearrangement products, and the major products were deallylated ones. However, the corresponding tertiary anilines rearranged in practical yields. *Para* rearrangement products were observable only when

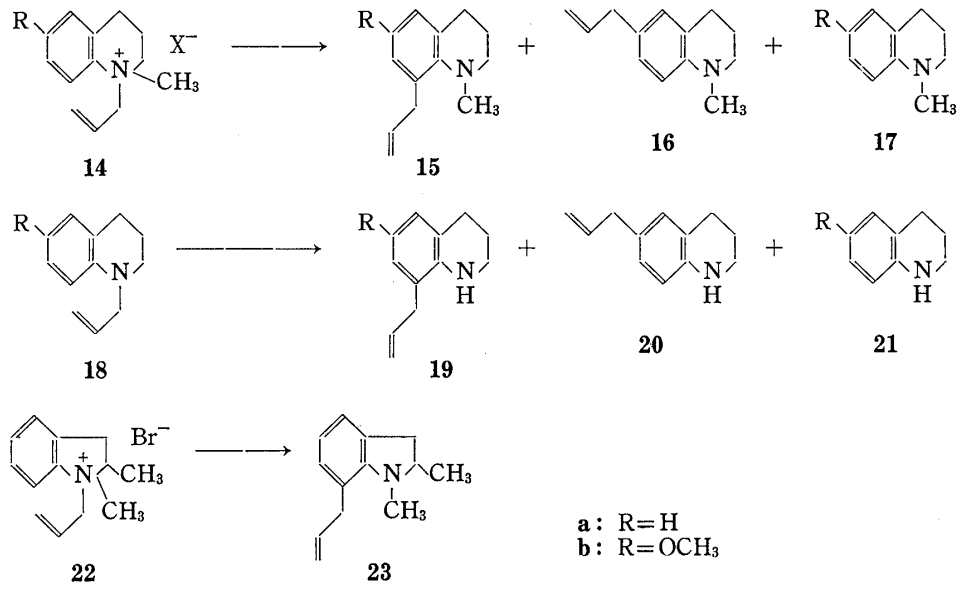

Chart 5

the *ortho* substituent was a methyl group and were indetectable in the case of an *ortho* methoxy group.[7]

N-Claisen Rearrangements of 1,2,3,4-Tetrahydroquinoline and Indoline Derivatives

Based upon the above observations of the quaternary N-Claisen rearrangement we were interested in the framework of 1,2,3,4-tetrahydroquinoline in which the *ortho* substituent is locked in a ring, thus being free from steric interaction between the *ortho* substituent and N-substituent. 1-Allyl-1-methylterahydroquinolinium halides **14** were prepared by treatment of the kairolines **17** with allyl halides. Quaternary N-Claisen rearrangement of **14** gave the *ortho* rearrangement products **15** almost as sole products in good yields. The presence of an additional substituent (R=OCH_3) on the aromatic ring did not affect the course of rearrangement (*e.g.* **14b**). The counter ion effect upon quaternary N-Claisen rearrangement, observable in the reaction of **14a** (X=Cl, Br, I), was in accord with that observed previously.[1] Indoline can also be regarded as an aniline derivative with a locked *ortho* substituent. 1-Allyl-1,2-dimethylindolinium bromide **22**, which was prepared from 1,2-dimethylindoline and was a mixture of *cis* and *trans* stereoisomers, rearranged into the *ortho* product **23** in good yield. These quaternary N-Claisen rearrangements may represent a practical method to introduce an allyl function *ortho* (*peri*) to the tertiary nitrogen atom. For comparison of the quaternary N-Claisen rearrangement with the tertiary one, the corresponding tertiary amines, 1-allyl-

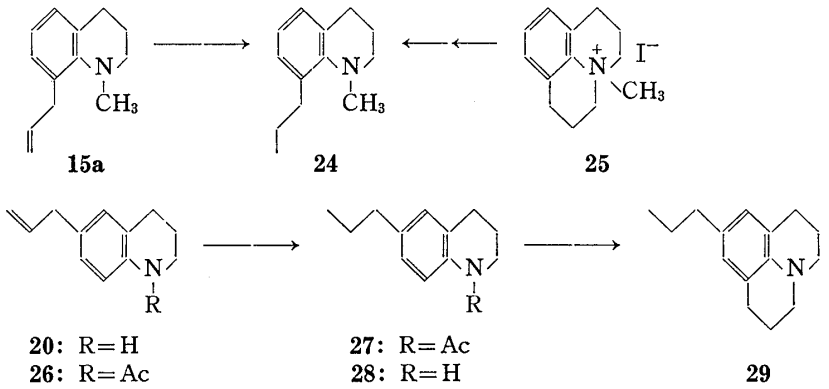

Chart 6

tetrahydroquinolines **18**, were prepared by treatment of the tetrahydroquinolines **21** with allyl bromide. Rearrangement of **18** under reaction condition C or D gave the *ortho* rearrangement products **19** in good yields (Table I). In contrast to the quaternary N-Claisen rearrangement, the tertiary amine **18a** yielded the *para* rearrangement product **20** in 8% yield under reaction condition C. The effect of a *para*-methoxy substituent upon the tertiary N-Claisen rearrangement was indetectable in the reaction of **18b**. The photochemical behavior of **18a** was also investigated, since photochemical [3, 3] sigmatropic rearrangement is disallowed by the Woodward-Hoffmann conservation rule. The product was a mixture of **19a** (4%), **20** (31%) and **21a** (42%), derived by radical reaction.[8] Since the ratio of these products could be representative of the dissociation-recombination mechanism, the marked discrepancy of the products pattern between the photochemical and rearrangement reactions might be indicative that N-Claisen rearrangement of **18** could be an intramolecular [3, 3] sigmatropic reaction.

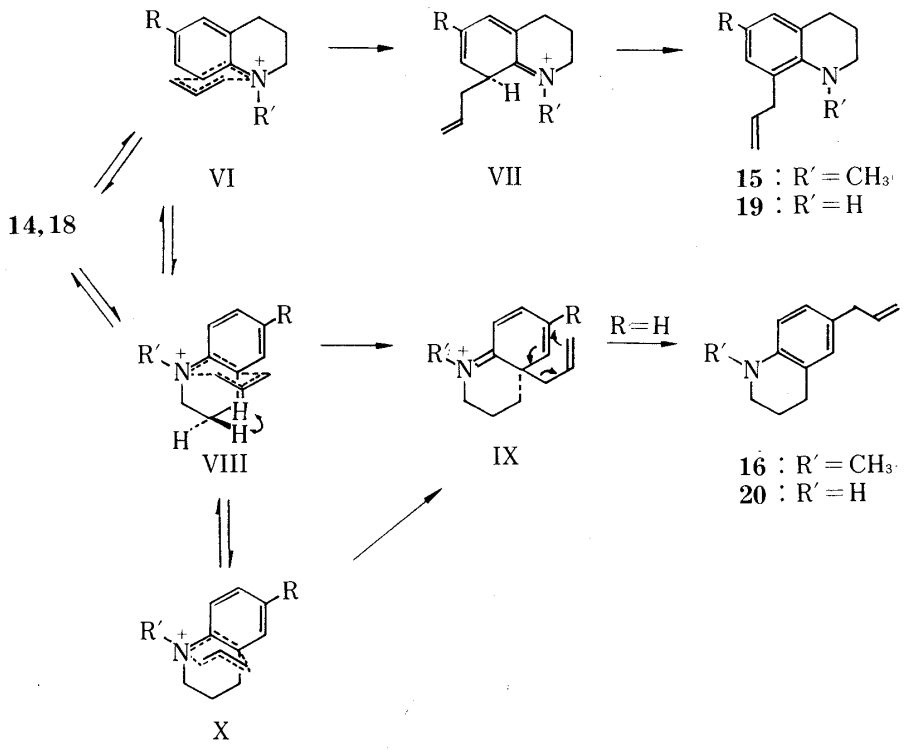

Chart 7

Rearrangement products were characterized and their identities confirmed as shown in Chart 6. Secondary amines **19** were correlated with **15** by methylation. The product **15a** was derived to **24**, which was identical with 1-methyl-8-propyl-1,2,3,4-tetrahydroquinoline obtained from 4-methyljulolidinium iodide **25** by Hofmann degradation and subsequent catalytic hydrogenation. The structure of **15b** was deduced similarly by analogy with **15a** and was supported by *meta* couplings (J=2.5 Hz) of the aromatic protons (δ 6.50 and 6.57) in the NMR spectrum. The structure of **23** was assigned in the same way as that of **15b**. The *para* rearrangement product **20** was converted into 9-propyljulolidine **29** by a series of reactions. The NMR spectrum of **29** was suggestive of a symmetrical structure thus determining the position of the allyl group of **20**. The above results on the quaternary N-Claisen rearrangement of N-allylated tetrahydroquinolinium and indolinium compounds can be understood by a consideration of the reaction pathways (Chart 7). The bulky N-allyl substituent of the tetrahydroquinoline framework tends to take a *quasi*-axial configuration, requisite for the rearrangement, in order to ease the *peri* interaction between N-allyl and C-8-H functions. This conformational preference of the N-allyl group should be responsible for the successful

quaternary N-Claisen rearrangement of **14** and **22**. There are two possible transition states VI ($R'=CH_3$) and VIII ($R'=CH_3$) for the rearrangement of **14**. The transition state VI ($R'=CH_3$), corresponding to the *ortho* rearrangement product **15**, is energetically more stable than the transition state VIII ($R'=CH_3$), because in the latter state there is severe steric interaction between C-3-H and the vinylic proton as shown in VIII. This interaction could be avoided by switching the conformations of the transition states from chair form VIII into boat form X, although the boat form is in general less favorable than the chair form for [3, 3] sigmatropic rearrangement[9] owing to energy requirements. The preference for the transition state VI ($R'=CH_3$) over VIII ($R'=CH_3$) and X ($R'=CH_3$) leads to the exclusive formation of the *ortho* rearrangement product **15** in the quaternary N-Claisen rearrangement of **14**. The tertiary amine **18a** under reaction condition C gave the *para* rearrangement product **20** in 8% yield. Under reaction condition C, bulky BF_3 might associate onto the nitrogen atom and initiate the rearrangement. Although the reason in unclear, this association might have reduced the difference of stability between VI ($R'=BF_3$) and X ($R'=BF_3$) and led to the formation of the *para* rearrangement product **20**.

In conclusion, the quaternary N-Claisen rearrangement can operate in an N-allylated anilinium compound with an *ortho* substituent unless the *ortho* substituent prevents the allyl moiety on the nitrogen atom from adopting suitable conformations for the rearrangement. N-Claisen rearrangement of tertiary anilines can take place more readily and have wider applicability than that of quaternary ones. However, the quaternary N-Claisen rearrangement is quite useful to introduce alkyl and other substituents derivable from an allyl group at the *ortho* site of the N,N-disubstituted aniline skeleton intramolecularly from the aniline nitrogen atom. There is no other method, to our knowledge, to achieve this. Attempts at the rearrangements of N-allylated anilinium compounds in which the two *ortho* or *ortho* plus *para* sites are substituted as rings are in progress.[10]

Experimental

Physical measurements were carried out on the following machines: IR, Hitachi 215 grating infrared spectrometer; UV, Shimadzu UV-200; NMR, JEOL JNM-PMX 60; GLC, Hitachi 163 (FID detector) or 164 (TCD detector). NMR spectra were taken in $CDCl_3$ with tetramethylsilane as an internal standard unless otherwise specified (abbreviations: s=singlet, d=doublet, t=triplet, q=quartet, m=multiplet). GLC was carried out with 10% SE-30 (glass column 3 mm×2 m) as the liquid phase at an N_2 flow rate of 20—30 ml/min at 200—230°C. Mps were measured with a Yanaco MP-3 hot stage apparatus. Mp and bp values are uncorrected. Silica gel (SiO_2) for column chromatography was Wakogel C-200, and Merck silica gel 60 (230—400 mesh) was used for flush column chromatography.[11] TLC procedures were performed on Merck TLC plates (silica gel 60 F_{254}), HPTLC plates (silica gel 60 F_{254}) and PLC plates (silica gel 60 F_{254}). Extractions were repeated three times with organic solvents, and organic extracts were washed twice with saturated brine, dried over anhydrous Na_2SO_4 for basic compounds or over anhydrous $MgSO_4$ for neutral compounds.

General Procedures for N-Claisen Rearrangement——a) Reaction condition A[1] A solution of quaternary salt (2.0 mmol) in glycerol-water (2/1, 6 ml) was heated at 140°C (bath temperature) for 2—4 h. The reaction mixture was basified with Na_2CO_3 and extracted with ether.

b) Reaction condition B[1] The reaction was carried out as described above, but in the presence of $NaHCO_3$ (2.2 mmol), then the reaction mixture was diluted with brine and extracted.

c) Reaction condition C[4] N-Allylated tertiary amine (2.0 mmol) and BF_3 etherate (4.2 mmol) were heated at 140°C for 2 h. The resulting paste was treated with aqueous Na_2CO_3 and extracted with ether.

d) Reaction condition D[5] N-Allylated tertiary amine (2 mmol) in 2 N H_2SO_4 in glycerol-water (2/1, 6 ml) was heated at 140°C (bath temperature). The progress of reaction was followed by TLC. The reaction mixture was basified with Na_2CO_3 and worked up.

N-Allyl-N,N-dimethyl-*o*-toluidinium Bromide 1a——N,N-Dimethyl-*o*-toluidine **4a** (1.6 g), allyl bromide (10 g) and three drops of DMF in MeCN (30 ml) were left at room temperature for 11 days. The crude crystals (1.17 g), a mixture of **1a** and **4a**: **HBr** (42/58 by NMR integration), were washed with hot acetone to remove the hydrobromide, giving 0.13 g (10.2%) of **1a**: mp 158.5—159.5°C (dec, in a seated tube) (CH_2Cl_2–acetone); IR ν_{max}^{KBr} cm^{-1}: 950, 850, 785; NMR δ: 2.87 (3H, s, Ar–Me), 4.10 (6H, s, NMe_2), 5.17 (2H, m, $C\underline{H}_2$–$CH=CH_2$), 5.3—5.9 (3H, m, CH_2–$C\underline{H}=CH_2$), 7.50 (3H, m, Ar–H), 7.87 (1H, m, Ar–H). *Anal.* Calcd for $C_{12}H_{18}BrN$: C, 56.26; H, 7.08; N, 5.47; Br, 31.19%. Found: C, 56.51, H, 7.16; N, 5.35; Br, 31.43%.

N-Allyl-N,N-dimethyl-*o*-anisidinium Bromide 1b——N,N-Dimethyl-*o*-anisidine **4b** (5.2 g) and allyl bromide (5.1 g) in acetone (30 ml) were refluxed for 9 h, giving **1b** in 34% yield. **1b**: mp 188—193°C (dec, in a sealed tube) (CH_2Cl_2–acetone); IR ν_{max}^{KBr} cm^{-1}: 1640, 1265, 1008, 772; NMR δ ($CDCl_3/CD_3OD=2/1$): 3.77 (3H, s, NMe), 3.79 (2H, overlapping with NMe, $C\underline{H}_2$–CH=CH_2), 3.80 (3H, s, NMe), 4.13 (3H, s, OMe), 4.80 (1H, m, vinylic H), 5.57 (2H, m, vinylic H), 7.1—7.9 (4H, m, Ar–H). *Anal.* Calcd for $C_{12}H_{18}BrNO$: C, 52.95; H, 6.66; N, 5.15; Br, 29.36%. Found: C, 52.66; H, 6.62; N, 5.05; Br, 29.17%.

Rearrangement of 1a——The quaternary bromide **1a** (185 mg, 0.72 mmol) was treated under condition B. The crude product was a mixture of **4a** (40.5%), **5a** (9.9%), **2a** (38.2%), **3a** (2.1%) and two other products as determined by GLC analysis. The combined products (122 mg) were flusch-chromatographed on SiO_2 (9.0 g) with petroleum ether (PE)/EtOAc (98/2) to give 22 mg of **2a**, which was identical (TLC, GLC and NMR spectrum) with the specimen prepared by the methylation of **6a**, 6 mg of **5a** (52% purity) and 8 mg of **4a**. The presence of **3a** was confirmed by detailed analyses of the polar fraction (8 mg) of the reaction products by TLC and GLC in comparison with an authentic specimen of **3a** which was derived from **7a** by methylation, *vide infra*.

Rearrangement of 1b——The combined crude product (400 mg) obtained by the rearrangement of **1b** under condition B was chromatographed on SiO_2 (10 g) with benzene–ether to give **2b** (10 mg), which was identified with the specimen derived from **6b** by methylation, **5b** (70 mg) and **4b** (188 mg). These products were identified by TLC and NMR comparisons.

N-Allyl-N-methyl-*o*-toluidine 5a——N,N-Dimethyl-*o*-toluidine **4a** (3.65 g) and a large excess of allyl bromide in MeCN (70 ml) were refluxed for 68 h. The reaction products were separated into the ether-soluble part (2.60 g) and the ether–insoluble part (1 g), of which the latter contained impure **1a** (284 mg, 5.5%). The former (2.60 g) was a mixture of **4a** (55%) and **5a** (45%). This mixture was chromatographed on SiO_2 (4.0 g) with CH_2Cl_2 to yield **4a** (0.47 g) and **5a** (0.71 g). **5a**: IR ν_{max}^{film} cm^{-1}: 1620, 920, 765, 725; NMR δ: 2.33 (3H, s, Ar–Me), 2.70 (3H, s, NMe), 3.53 (2H, d, $J=5.5$ Hz, $C\underline{H}_2$–CH=CH_2), 5.13, 5.30 and 5.47 (2H, each m, CH_2–CH=$C\underline{H}_2$), 6.03 (1H, tdd, $J=5.5$, 10, 18 Hz; doublet d, $J=10$, 18 Hz, on irradiation at δ 3.53, CH_2–CH=$C\underline{H}_2$), 7.20 (4H, m, Ar–H). Picrate: mp 136—142°C. *Anal.* Calcd for $C_{17}H_{18}N_4O_7$: C, 52.31; H, 4.65; N, 14.35. Found: C, 52.44, H, 4.61; N, 14.49.

N-Allyl-N-methyl-*o*-anisidine 5b[12]——MS *m/e*: 177 (M^+); IR ν_{max}^{film} cm^{-1}: 1620, 1242, 1025, 920, 743; NMR δ: 2.77 (3H, s, NMe), 3.72 (2H, d, $J=6$ Hz, $C\underline{H}_2$–CH=CH_2), 3.90 (3H, s, OMe), 5.07 and 5.27 (2H, each m, CH_2–CH=$C\underline{H}_2$), 5.97 (1H, tdd, $J=6$, 9, 17.5 Hz, CH_2–$C\underline{H}$=CH_2), 6.93 (4H, s, Ar–H). Picrate: mp 107—109°C (EtOH). *Anal.* Calcd for $C_{17}H_{18}N_4O_8$: C, 50.25; H, 4.46; N, 13.79. Found: C, 50.39; H, 4.45; N, 13.26.

Rearrangement of 5a——a) The allylamine **5a** (320 mg, 2 mmol) was reacted under condition C at 150°C for 3 h to give 294 mg of crude product consisting of at least seven compounds, four of which were **8a** (9.5%), **5a** (4.0%), **6a** (61.3%) and **7a** (14.4%). The crude product was separated twice by flush column chromatography (1. 187 mg, SiO_2 15 g, PE/EtOAc=94/6; 2. 143 mg, SiO_2 8 g, CH_2Cl_2/PE=8/2). The deallylated product **8a** (13 mg) was obtained in 61% purity and was shown to be identical with an authentic specimen by NMR, TLC and GLC. The major product was 3-allyl-2-methylaminotoluene **6a** (55 mg): IR ν_{max}^{film} cm^{-1}: 3400, 1468, 913, 762; NMR δ: 2.30 (3H, s, Ar–Me), 2.73 (3H, s, NMe), 3.13 (1H, broad s, NH; disappeared on D_2O addition), 3.43 (2H, td, $J=1.2$, 5 Hz, $C\underline{H}_2$–CH=CH_2), 4.8—5.3 (2H, m, CH_2–CH=$C\underline{H}_2$), 6.00 (1H, m, CH_2–$C\underline{H}$=CH_2), 6.97 (3H, m, Ar–H).

b) The allylamine **5a** (322 mg, 2 mmol) was treated under condition D for 23 h. The crude product (300 mg) was a mixture of at least seven products, four of which were **8a** (0.5%), **5a** (2.7%), **6a** (38%) and **7a** (7.5%). Flush column chromatography of the crude product (SiO_2 20 g, PE/EtOAc=95/5) gave 91 mg of **5a**, 10 mg of an unidentified product and 125 mg of **6a**. The *para* rearrangement product **7a** could not be isolated in a pure state from the reaction products but was characterized after conversion into **3a** by methylation.

Methylation[6] **of a Mixture of 6a and 7a**——The rearrangement product **6a** (154 mg) contaminated with **7a** (28%) was dissolved in MeCN (5 ml). Next, 37% HCHO (0.8 ml) and $NaBH_3CN$ (218 mg) were added and reduction was initiated by adding AcOH (0.15 ml) dropwise. After 45 min another 0.1 ml of AcOH was added and the reaction was continued for 0.5 h. The reaction mixture was evaporated to dryness. The residue was diluted with aqueous Na_2CO_3 and extracted with ether to give 155 mg of crude product. The combined crude products (180 mg) were subjected to flush column chromatography (SiO_2 9.0 g, PE/EtOAc=98/2) to give pure **2a** (115 mg) and pure **3a** (27 mg). 3-Allyl-2-dimethylaminotoluene **2a**: MS *m/e*: 175 (M^+); IR ν_{max}^{film} cm^{-1}: 1640, 908, 768; NMR δ: 2.37 (3H, s, Ar–Me), 2.87 (6H, s, NMe_2), 3.53 (2H, td, $J=1.5$, 6 Hz, $C\underline{H}_2$–CH=CH_2), 5.00 and 5.20 (2H, each m, CH_2–CH=$C\underline{H}_2$), 6.10 (1H, m, CH_2–$C\underline{H}$=CH_2), 7.13 (3H, s, Ar–H). Picrate: yellow needles, mp 133—134°C (EtOH). *Anal.* Calcd for $C_{18}H_{20}N_4O_7$: C, 53.46; H, 5.00; N, 13.86%. Found: C, 53.37; H, 4.89; N, 13.71%. 4-Allyl-2-methyl-N,N-dimethylaniline **3a**: MW *m/e*: 175 (M^+); IR ν_{max}^{film} cm^{-1}: 1640, 914, 815; NMR δ: 2.33 (3H, s, Ar–Me), 2.70 (6H, s, NMe_2), 3.37 (2H, d, $J=7$ Hz, $C\underline{H}_2$–CH=CH_2), 5.04 and 5.27 (2H, each m, CH_2–CH=$C\underline{H}_2$), 6.10 (1H, m, CH_2–$C\underline{H}$=CH_2), 7.07 (3H, s, Ar–H). Picrate: yellow needles, mp 108—109.5°C (EtOH). *Anal.* Calcd for $C_{18}H_{20}N_4O_7$: C, 53.46; H, 5.00; N, 13.86%. Found: C, 53.22; H, 4.77; N, 13.85%.

Hofmann Degradation of 9a——1,1,8-Trimethyl-1,2,3,4-tetrahydroquinolinium iodide **9a**[13] (390 mg,

1.3 mmol), mp 203—205°C (dec.), was treated with *t*-BuOK (560 mg, 5 mmol) in anhydrous *t*-BuOH (10 ml) at refluxing temperature for 2 h under N_2. Usual work-up gave 179 mg of liquid product which was purified by flush column chromatography (SiO_2 3.5 g, PE/EtOAc=98/2) to give 1,8-dimethyl-1,2,3,4-tetrahydroquinoline[13] (53 mg, 26%), hydrochloride mp 156—157.5°C (dec.), and 3-allyl-2-dimethylaminotoluene (16.5 mg, 7.3%) identical with **2a** as judged by TLC, GLC and NMR spectroscopy.

2-Allyl-4-methyl-N,N-dimethylaniline 13——a) N,N-Dimethyl-*p*-toluidine (5 g) and allyl bromide (10 g) were dissolved in MeOH (20 ml)–acetone (30 ml) and refluxed for 8 h. Concentration of the reaction mixture *in vacuo* gave noncrystallizable N-allyl-N,N-dimethyl-*p*-toluidinium bromide; NMR δ: 2.37 (3H, s, Ar–Me), 3.90 (6H, s, NMe_2), 5.07 (2H, m, $C\underline{H}_2$–CH=CH_2), 5.40—5.80 (3H, m, CH_2–C$\underline{H}$=CH_2), 7.41 (2H, A part of A_2B_2 type, J=9 Hz, Ar–H), 7.92 (2H, B part of A_2B_2 type, J=9 Hz, Ar–H). This bromide (1.34 g, 5.2 mmol) was dissolved in water (20 ml) and treated with $NaBF_4$ (3.18 g, 29 mmol). Exchanged salt **12** was extracted twice with CH_2Cl_2 to give a pale yellow paste, which could not be crystallized, of N-allyl-N,N-dimethyl-*p*-toluidinium tetrafluoroborate **12**, IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1492, 1062, 960, 908; NMR δ: 2.40 (3H, s, Ar–Me), 3.57 (6H, s, NMe_2), 4.50 (2H, m, CH_2–CH=C$\underline{H}_2$), 5.57 (3H, m, CH_2–C$\underline{H}$=CH_2), 7.40 (2H, A part of A_2B_2 type, J=9 Hz, Ar–H), 7.66 (2H, B part of A_2B_2 type, J=9 Hz, Ar–H).

b) The salt **12** (1.02 g, 3.9 mmol) was treated under reaction condition B. The product (431 mg, 63.4%) was practically pure (97.4%) 2-allyl-4-methyl-N,N-dimethylaniline **13**, IR ν_{max}^{film} cm^{-1}: 2825, 2780, 1638, 1502, 910, 820; NMR δ: 2.27 (3H, s, Ar–Me), 2.63 (6H, s, NMe_2), 3.50 (2H, td, J=1.5 H, 6 Hz, Ar–C$\underline{H}_2$–CH=CH_2), 4.98 and 5.17 (2H, m,m, CH_2–CH=C$\underline{H}_2$), 6.03 (1H, tdd, J=6, 9, 17 Hz, CH_2–CH=C$\underline{H}_2$), 6.97 (3H, s, Ar–H). Picrate, mp 152—154°C. *Anal.* Calcd for $C_{18}H_{20}N_4O_7$: C, 53.46; H, 4.99; N, 13.86. Found: C, 53.36; H, 5.05; N, 13.76.

Rearrangement of 5b——The tertiary amine **5b** (526 mg, 3 mmol) was treated under reaction condition D for 60 h. The crude product (502 mg) was chromatographed on SiO_2 (15 g) using CH_2Cl_2 with gradual addition of acetone (1%, 3%, 5%) to give the first eluate (22 mg), **5b** (76 mg, 14.4%) and **6b** (42 mg, 46%). 3-Allyl-2-methylaminoanisole **6b**: MS *m/e*: 177 (M^+); IR ν_{max}^{film} cm^{-1}: 3380, 1638, 1250, 1070, 745; NMR δ: 2.83 (3H, s, NMe), 3.50 (2H, td, J=1.5, 6 Hz, C$\underline{H}_2$–CH=CH_2), 3.50 (1H, broad, NH; disappeared on D_2O addition), 3.83 (3H, s, OMe), 5.00 and 5.23 (2H, each m, CH_2–CH=C$\underline{H}_2$), 6.07 (1H, tdd, J=6, 9, 17.5 Hz, CH_2–C$\underline{H}$=CH_2), 6.83 (3H, m, Ar–H). Picrate: yellow rods, mp 124.5—125.5°C (dec.) (EtOH). *Anal.* Calcd for $C_{17}H_{18}N_4O_8$: C, 50.25; H, 4.46; N, 13.79. Found: C, 50.30; H, 4.44; N, 13.80. The first eluate (22 mg) was a mixture of two major compounds (38% and 49%) and its NMR spectrum was indicative of the following functional groups: *sec*-Me: 1.03 (d, J=6 Hz); NMe: 2.57 (s); OMe: 3.83 (s); CH_2–CH=CH_2: 3.37 (d, J=6 Hz), 4.96 and 5.20 (each m), 5.90 (m). The absence of contamination by **7b** was confirmed by detailed TLC analysis of the first eluate.

Methylation of 6b——The secondary amine **6b** (164 mg, 1 mmol), 37% HCHO (0.8 ml) and $NaBH_3CN$ (225 mg, 3.6 mmol) were dissolved in MeCN (5 ml) and the solution was stirred vigorously. AcOH (0.15+0.1 ml) was added in two portions over a period of 1 h. After 1.5 h, the reaction mixture was worked up to give 173 mg of liquid product, which was purified by column chromatography (SiO_2 2.7 g, CH_2Cl_2), giving 3-allyl-2-dimethylaminoanisole **2b**: MS *m/e*: 191 (M^+); IR ν_{max}^{film} cm^{-1}: 1640, 1080, 755; NMR δ: 2.77 (6H, s, NMe_2), 3.53 (2H, td, J=1.3, 6.5 Hz, C$\underline{H}_2$–CH=CH_2), 3.86 (3H, s, OMe), 4.96 and 5.17 (2H, each m, CH_2–CH=C$\underline{H}_2$), 6.08 (1H, tdd, J=6.5, 9.5, 18 Hz, CH_2–C$\underline{H}$=CH_2), 6.7—7.3 (3H, m, Ar–H). Picrate: yellow plates, mp 102—103°C (EtOH). *Anal.* Calcd for $C_{18}H_{20}N_4O_8$: C, 51.43; H, 4.80; N, 13.33. Found: C, 51.39; H, 4.78; N, 13.37.

2-Dimethylamino-3-propylanisole 11——a) 1,1-Dimethyl-8-methoxy-1,2,3,4-tetrahydroquinolinium iodide[13] **9b** (1.06 g, 3.3 mmol) was added to 1 M *t*-BuOK in *t*-BuOH (50 ml) and the reaction mixture was gently refluxed for 2.5 h. The crude product (610 mg) was chromatographed on SiO_2 (15 g) with CH_2Cl_2–EtOAc (97.5/2.5) to give the demethylated product, 1-methyl-8-methoxy-1,2,3,4-tetrahydroquinoline[14] (447 mg, 76%) and the degradation product **10** (133 mg, 21%), 2-dimethylamino-3-(1′-propenyl)anisole: a mixture of *trans* and *cis* isomers (92.7/6.3); MS (both isomers had identical fragmentation patterns), *m/e*: 191 (M^+, base peak), 186, 162, 147; IR ν_{max}^{film} cm^{-1}: 2790, 1650, 1255, 772, 742; NMR δ: 1.90 (3H, dd, J=1.5, 6.5 Hz, C$\underline{H}$Me), 2.77 (6H, s, NMe_2), 3.80 (3H, s, OMe), 6.13 (1H, qd, J=6.5, 16 Hz, *trans* CH=C$\underline{H}$Me; doublet, J=16 Hz, on irradiation at δ 1.90), 6.63—7.17 (4H, m, Ar–C$\underline{H}$=CHMe+Ar–H).

b) A solution of **10** (108 mg) in EtOAc (15 ml) was hydrogenated over 5% Pd–C (44 mg) to give a colorless liquid product (97 mg), 2-dimethylamino-3-propylanisole **11**: IR ν_{max}^{film} cm^{-1}: 2790, 1580,1470,1257, 1082, 752; NMR δ: 0.93 (3H, t, J=7 Hz, C$\underline{H}$Me), 1.60 (2H, m, $CH_2C\underline{H}_2$Me), 2.07 (2H, t, J=7 Hz, Ar–C$\underline{H}_2$–Et), 2.77 (6H, s, NMe), 3.80 (3H, s, OMe), 6.6—7.2 (3H, m, Ar–H). Picrate: mp 149—151°C. *Anal.* Calcd for $C_{18}H_{22}N_4O_8$: C, 51.18; H, 5.25; N, 13.26. Found: C, 51.09; H, 5.26; N, 13.30.

c) 3-Allyl-2-dimethylaminoanisole **2b** (45 mg) in EtOAc (15 mg) was similarly hydrogenated over 5% Pd-C to give a colorless liquid (34 mg), identical with 2-dimethylamino-3-propylanisole **11** as judged by TLC, GLC and NMR comparisons.

1-Allyl-1-methyl-1,2,3,4-tetrahydroquinolinium Chloride 14a: X=Cl——1-Methyl-1,2,3,4-tetrahydroquinoline (kairoline) **17a** (965 mg) and allyl chloride (15 ml) in EtOH (15 ml) were refluxed for 13.5 h in the presence of molecular sieves 4A to give hygroscopic crystals (551 mg, 38%) of **14a**: X=Cl; mp 158—159.5°C (dec.) ($CHCl_3$–acetone); IR ν_{max}^{KBr} cm^{-1}: 3050, 2855, 1498; NMR δ: superimposable on that of the bromide.

Anal. Calcd for $C_{13}H_{18}ClN$: C, 69.79; H, 8.11; N, 6.26; Cl, 15.84. Found: C, 69.33; H, 8.14; N, 5.92; Cl, 16.51.

1-Allyl-1-methyl-1,2,3,4-tetrahydroquinolinium Bromide 14a: X=Br——Kairoline **17a** (6.4 g) and allyl bromide (10 g) in MeCN (100 ml) were refluxed for 8 h to give the highly hygroscopic bromide in 50% yield, **14a: X=Br**: mp 120—124°C (CH_2Cl_2–acetone); IR ν_{max}^{KBr} cm^{-1}: 3040, 1478, 1490; NMR δ: 2.34 (2H, m, C-3-H), 3.06 (2H, t, $J=6$ Hz, C-4-H), 3.96 (3H, s, NMe), 4.27 (2H, m, C-2-H), 5.17 (2H, m, $C\underline{H}_2$–CH=CH_2), 5.5—6.0 (3H, m, CH_2–$C\underline{H}$=CH_2), 7.43 (3H, m, Ar–H), 8.40 (1H, m, Ar–H). *Anal.* Calcd for $C_{13}H_{18}BrN$: C, 58.22; H, 6.73; N, 5.22; Br, 29.76. Found: C, 58.06; H, 6.69; N, 5.30; Br, 29.75.

1-Allyl-1-methyl-1,2,3,4-tetrahydroquinolinium Iodide 14a: X=I[15]——mp 129—131.5°C (dec.) ($CHCl_3$–acetone). IR ν_{max}^{KBr} cm^{-1}: 3080, 1490; *Anal.* Calcd for $C_{13}H_{18}IN$: C, 49.54; H, 5.76; N, 4.44; I, 40.26%. Found: C, 49.74; H, 6.03; N, 4.49; I, 40.65%.

1-Allyl-1-methyl-6-methoxy-1,2,3,4-tetrahydroquinolinium Bromide 14b: X=Br——1-Methyl-6-methoxy-1,2,3,4-tetrahydroquinoline **17b**[16a] (1.70 g) and allyl bromide (7.5 g) in acetone (30 ml) were refluxed for 6 h to give 2.0 g (70%) of **14b: X=Br**; highly hygroscopic amorphous solid, mp 102—105°C (in a sealed tube); NMR δ: 2.30 (2H, m, C-3-H), 3.00 (2H, t, $J=6.5$ Hz, C-4-H), 3.83 (3H, s, OMe), 3.90 (3H, s, NMe), 4.20 (2H, m, C-2-H; AB type, $J=6.5$ Hz on irradiation at δ 2.30), 5.13 (2H, broad s, $C\underline{H}_2$–CH=CH_2), 5.5—6.0 (3H, m, CH_2–$C\underline{H}$=$C\underline{H}_2$), 6.70 (1H, d, $J=3$ Hz, C-5-H), 7.00 (1H, dd, $J=3$, 9 Hz, C-7-H), 8.83 (1H, d, $J=$ 9 Hz, C-8-H).

1-Allyl-1,2-dimethylindolinium Bromide 22——The reaction of 1,2-dimethylindoline[1] and allyl bromide gave 1-allyl-1,2-dimethylindolinium bromide **22** in 60% yield as a mixture of two stereoisomers: mp 164.5—165°C (MeOH–acetone); IR ν_{max}^{KBr} cm^{-1}: 3080, 1482; NMR δ: (*trans*/*cis*=1/2) 1.66 (d, $J=6.5$ Hz, *trans* CH$\underline{Me}$), 1.81 (d, $J=6.5$ Hz, *cis* CH$\underline{Me}$), 3.30 (s, *trans* NMe), 3.57 (s, *cis* NMe), 4.15 (2H, d, $J=5.5$ Hz, $C\underline{H}_2$–CH=CH_2), 5.65 (3H, m, vinylic H), 7.54 (4H, m, Ar–H). *Anal.* Calcd for $C_{13}H_{18}BrN$: C, 58.22; H, 6.76; N, 5.22; Br, 29.80. Found: C, 58.07; H, 6.92; N, 5.41; Br, 29.82.

Rearrangement of 14a——The crude product (3.313 g) obtained from **14a** (5.30 g, 20 mmol) under reaction condition B was subjected to bulb-to-bulb distillation at 128°C/8 mmHg to give 2.155 g of 8-allyl-1-methyl-1,2,3,4-tetrahydroquinoline **15a**: IR ν_{max}^{film} cm^{-1}: 1640, 910; NMR δ: 1.83 (2H, m, C-3-H), 2.70 (3H, s, NMe), 2.80 (2H, m, C-4-H), 3.10 (2H, m, C-2-H), 3.47 (2H, d, $J=6$ Hz, $C\underline{H}_2$–CH=CH_2), 5.00 and 5.20 (2H, each m, CH_2–CH=$C\underline{H}_2$), 6.07 (1H, tdd, $J=6$, 9, 17.5 Hz, CH_2–$C\underline{H}$=CH_2), 6.93 (3H, m, Ar–H). Picrate: yellow rods, mp 119—120°C (EtOH). *Anal.* Calcd for $C_{19}H_{20}N_4O_2$: C, 54.81; H, 4.84; N, 13.46%. Found: C, 54.70; H, 4.86; N, 12.97%.

Rearrangement of 14b: X=Br——The bromide **14b** (599 mg, 2 mmol) was reacted under condition B for 4 h. The brown liquid product (386 mg) containing **15b** (96%) and **17b** (3%) was purified by column chromatography (SiO_2 2 g, CH_2Cl_2) to give 360 mg (83%) of 8-allyl-6-methoxy-1,2,3,4-tetrahydroquinoline **15b**: MS *m/e*: 217 (M^+); IR ν_{max}^{film} cm^{-1}: 1640, 1060, 910; NMR δ: 1.87 (2H, m, C-3-H), 2.63 (3H, s, NMe), 2.80 (2H, t, $J=6.5$ Hz, C-4-H), 3.10 (2H, m, C-2-H), 3.47 (2H, d, $J=6.5$ Hz, $C\underline{H}_2$–CH=CH_2; singlet on irradiation at δ 6.03), 3.73 (3H, s, OMe), 5.03 and 5.23 (2H, each m, CH_2–CH=$C\underline{H}_2$), 6.03 (1H, tdd, $J=6$, 9, 17 Hz, CH_2–$C\underline{H}$=CH_2), 6.50 (1H, d, $J=2.5$ Hz, Ar–H), 6.67 (1H, d, $J=2.5$ Hz, Ar–H). Hydrochloride: colorless needles, mp 172.5—173.5°C (dec.) (acetone); IR ν_{max}^{KBr} cm^{-1}: 2450, 1642, 1160, 875; NMR δ: 2.23 (2H, m, C-3-H), 3.00 (2H, t, $J=7$ Hz, C-4-H), 3.13 (3H, s, NMe), 3.63 (2H, t, $J=5.5$ Hz, C-2-H), 3.80 (3H, s, OMe), 3.93 (2H, d, $J=6$ Hz, $C\underline{H}_2$–CH=CH_2), 5.00, 5.10 and 5.27 (2H, m,m,s, CH_2–CH=$C\underline{H}_2$), 6.07 (1H, m, CH_2–$C\underline{H}$=CH_2), 6.60 (1H, d, $J=3$ Hz, Ar–H), 6.73 (1H, d, $J=2.5$ Hz, Ar–H). *Anal.* Calcd for $C_{14}H_{20}ClNO$: C, 66.26; H, 7.94; N, 5.52; Cl, 13.97. Found: C, 66.42; H, 8.05; N, 5.53; Cl, 14.05.

Rearrangement of 22——The bromide **22** (1.293 g, 4.8 mmol) was reacted under condition B under N_2 to give 840 mg of liquid 7-allyl-1,2-dimethylindoline **23**: IR ν_{max}^{film} cm^{-1}: 3080, 1630; UV λ_{max}^{MeOH} nm (log ε): 256 (3.73), 295 (3.26); NMR δ: 1.28 (3H, d, $J=5.5$ Hz, CH$\underline{Me}$), 2.86 (3H, s, NMe), 3.45 (2H, d, $J=5.5$ Hz, $C\underline{H}_2$–CH=CH_2), 2.3—3.5 (3H, m, C-2-H+C-3-H), 4.92 and 5.16 (2H, each m, CH_2–CH=$C\underline{H}_2$), 6.03 (1H, m, CH_2–$C\underline{H}$=CH_2), 6.5—7.0 (3H, m, Ar–H). Picrate: yellow needles, mp 114—117.5°C (EtOH–acetone). *Anal.* Calcd for $C_{19}H_{20}N_4O_7$: C, 54.81; H, 4.84; N, 13.47. Found: C, 54.94; H, 5.02; N, 13.28. Hydrobromide: colorless rhombic crystals, mp 162—166°C ($CHCl_3$–acetone); IR ν_{max}^{KBr} cm^{-1}: 2750, 2698, 2640—2350, 1650, 1618; NMR δ (100 MHz): (a mixture of two stereoisomers) 1.69 (d, $J=6.5$ Hz) and 1.71 (d, $J=6.5$ Hz) (3H, CHMe), 2.87 (d, $J=5.3$ Hz) and 4.11 (d, $J=5.1$ Hz) (3H, HN$\underline{Me}$), 5.03 and 5.17 (2H, each m, CH_2–CH–$C\underline{H}_2$), 5.99 (3H, m, Ar–H). Catalytic hydrogenation of **23** in MeOH over 10% Pd–C yielded 7-propyl-1,2-dimethylindoline: IR ν_{max}^{film} cm^{-1}: 3070, 2800, 1600, 1585; NMR δ: 0.96 (3H, t, $J=7$ Hz, CH_2–CH_2–$\underline{Me}$), 1.28 (3H, d, $J=6$ Hz, CH$\underline{Me}$), 1.68 (2H, sextet, $J=7$ Hz, CH_2–$C\underline{H}_2$–Me), 2.86 (3H, s, NMe), 2.35—3.50 (5H, m, $C\underline{H}_2$–Et+C-2-H+C-3-H), 6.5—7.0 (3H, m, Ar–H). Picrate: mp 112—116.5°C (EtOH–$CHCl_3$).

1-Allyl-1,2,3,4-tetrahydroquinoline 18a[17]——bp 97°C/2 mmHg; UV λ_{max}^{MeOH} nm (log ε): 260 (3.99), 305 (3.37); IR ν_{max}^{film} cm^{-1}: 1612, 920, 750; NMR δ: 1.96 (2H, quintet, $J=6$ Hz, C-3-H), 2.78 (2H, t, $J=5$ Hz, C-4-H), 3.27 (2H, t, $J=5.5$ Hz, C-2-H), 3.88 (2H, d, $J=3$ Hz, $C\underline{H}_2$–CH=CH_2), 4.72 and 4.93 (2H, each m, CH_2–CH=$C\underline{H}_2$), 5.90 (1H, m, CH_2–$C\underline{H}$=CH_2), 6.4—6.7 (2H, m, Ar–H), 6.8—7.3 (2H, m, Ar–H). Picrate: mp 75.5—78°C (dec.) (CH_2Cl_2–ether). *Anal.* Calcd for $C_{18}H_{18}N_4O_7$: C, 53.73; H, 4.51; N, 13.92. Found: C, 53.75; H, 4.49; N, 14.21.

1-Allyl-6-methoxy-1,2,3,4-tetrahydroquinoline 18b[16b]——MS *m/e*: 203 (M^+); IR ν_{max}^{film} cm^{-1}: 1640, 1265;

NMR δ: 1.96 (2H, m, C-3-H), 2.80 (2H, d, J=6.5 Hz, C-4-H), 3.23 (2H, t, J=5.5 Hz, C-2-H), 3.77 (3H, s, OMe), 3.87 (2H, td, J=1.4, 5 Hz, C$\underline{H}_2$–CH=CH_2), 5.10 and 5.33 (2H, each m, CH_2–CH=C$\underline{H}_2$), 5.97 (1H, tdd, J=5, 9, 17 Hz, CH_2–C$\underline{H}$=CH_2), 6.63 (3H, s, Ar–H). Hydroiodide: mp 146—147°C (acetone). *Anal.* Calcd for $C_{13}H_{18}INO$: C, 47.15; H, 5.48; N, 4.23; I, 38.32%. Found: C, 47.07; H, 5.52; N, 3.96; I, 38.49%.

Rearrangement of 18a——a) The tertiary amine **18a** (1.74 g, 10 mmol) and freshly distilled BF_3 etherate (2.6 ml, 21.1 mmol) were heated at 180°C for 3.5 h. The reaction mixture was dissolved in aqueous Na_2CO_3 and extracted with ether three times. The crude product (1.567 g, 90%) was distilled by bulb-to-bulb distillation. The distillate (1.465 g) at 110—140°C/12 mmHg was chromatographed on SiO_2 (4 g) with a combination of hexane and CH_2Cl_2 (1: 1; 2: 3; 3: 7) to give 1.328 g (76%) of **19a** and 50 mg (3%) of **20**. 8-Allyl-1,2,3,4-tetrahydroquinoline **19a**: IR ν_{max}^{film} cm^{-1}: 3435, 1635, 925; NMR δ: 1.90 (2H, m, C-3-H), 2.78 (2H, t, J=6 Hz, C-4-H), 3.30 (4H, m, C-2-H+C$\underline{H}_2$–CH=CH_2), 3.68 (1H, broad m, NH; disappeared on D_2O addition), 4.97 and 5.20 (2H, each m, CH_2–CH=C$\underline{H}_2$), 5.97 (1H, tdd, J=5, 9, 18 Hz, CH_2–C$\underline{H}$=CH_2), 6.57 (1H, dd, J=5.5, 8 Hz, C-6-H), 6.88 (1H, d, J=8 Hz, C-7-H), 6.88 (1H, d, J=5.5 Hz, C-5-H). Picrate: yellow needles, mp 135—136°C (dec.) (CH_2Cl_2–ether). *Anal.* Calcd for $C_{18}H_{18}N_4O_7$: C, 53.73; H, 4.51; N, 13.92. Found: C, 53.80; H, 4.42; N, 13.59. 6-Allyl-1,2,3,4-tetrahydroquinoline **20**: colorless liquid; IR ν_{max}^{film} cm^{-1}: 3420, 1638, 907; NMR δ: 1.88 (2H, m, C-3-H), 2.72 (2H, t, J=6 Hz, C-4-H), 3.23 (4H, m, C-2-H+CH_2–C$\underline{H}$=CH_2), 3.60 (1H, s, NH; exchangeable with D_2O), 4.90 and 5.13 (2H, each m, CH_2–CH=C$\underline{H}_2$), 5.92 (1H, tdd, J=6, 9, 17 Hz, CH_2–C$\underline{H}$=CH_2), 6.40 (1H, d, J=8 Hz, C-8-H), 6.80 (2H, m, Ar–H). Picrate: yellow needles, mp 161—163°C (dec.) (CH_2Cl_2–ether). *Anal.* Calcd for $C_{18}H_{18}N_4O_7$: C, 53.73; H, 4.51; N, 13.92. Found: C, 53.72; H, 4.48; N, 13.82. Hydrochloride: colorless needles, mp 130—133°C (dec.) (acetone–ether); IR ν_{max}^{KBr} cm^{-1}: 2300—3000, 1640, 930, 818; NMR δ: 2.23 (2H, m, C-3-H), 2.89 (2H, t, J= 6 Hz, C-4-H), 3.37 (2H, d, J=5.5 Hz, C$\underline{H}_2$–CH=CH_2), 3.53 (2H, t, J=6 Hz, C-2-H), 4.97 and 5.18 (2H, each m, CH_2–CH=C$\underline{H}_2$), 5.95 (1H, m, CH_2–C$\underline{H}$=CH_2), 7.03 (1H, s, C-5-H), 7.10 (1H, d, J=8.5 Hz, C-7-H), 7.56 (1H, d, J=8.5 Hz, C-8-H).

b) The amine **18a** (349 mg, 2 mmol) was treated under condition D for 8 h. The crude product (335 mg) was subjected to column chromatography (SiO_2 11 g) with a combination of hexane–CH_2Cl_2 (1: 1; 2: 3; 1: 4) to give 186 mg (56%) of recovered **18a** and 126 mg of **19a** (36%; 77% based on the consumed starting material), which was identical with the specimen obtained in reaction a) as judged by TLC, GLC, and IR and NMR spectroscopy.

Irradiation of 18a——The allylamine **18a** (1.73 g) in dry benzene (250 ml) was irradiated with a 400W high-pressure mercury lamp (Hayashi Rikagaku Co., type UV-HT) while a purified dry N_2 was bubbled through the solution for 6 h. Concentration of the reaction mixture gave a brown product which was chromatographed on SiO_2 (60 g) with a combination of hexane–CH_2Cl_2 (1: 1; 2: 3; 1: 4) to give **18a** (121 mg 7%), fraction A (375 mg), fraction B (462 mg) and fraction C (192 mg). It was not possible to isolate **19a** in a pure state but its presence in fraction A was proved by GLC analysis (10% SE-30 and 15% QF-1 at 210°C; N_2 30 ml/min). Fraction B was mainly **21a** and the combined fraction B (785 mg) was purified by bulb-to-bulb distillation at 127°C/23 mmHg to give 333 mg of 1,2,3,4-tetrahydroquinoline **21a**. Fraction C was mainly **20**, contaminated with **21a**. Bulb-to-bulb distillation of the combined fraction C (357 mg) at 108°C/ 3 mmHg gave 180 mg of **20** of 88% purity. Further purification of this distillate was carried out by preparative TLC ($CHCl_3$/acetone=97/3) to afford 80 mg of pure **20**. The products **20** and **21a** were identified by comparison with authentic specimens (TLC, GLC and NMR spectroscopy).

Rearrangement of 18b——The amine **18b** (410 mg, 2 mmol) and BF_3 etherate (0.5 ml, 4.3 mmol) were heated at 150°C for 2.5 h. The crude product (288 mg) was chromatographed on SiO_2 (7 g) using CH_2Cl_2 with gradual addition of acetone (1%, 5%, 10%) to afford 235 mg (57%) of liquid 8-allyl-6-methoxy-1,2,3,4-tetrahydroquinoline **19b**: MS *m/e*: 203 (M^+); IR ν_{max}^{film} cm^{-1}: 3410, 1638, 1252, 1150, 1060, 912; NMR δ: 1.90 (2H, m, C-3-H), 2.83 (2H, t, J=6 Hz, C-4-H), 3.27 (2H, d, J=6 Hz, C$\underline{H}_2$–CH=CH_2; singlet on irradiation at δ 5.96), 3.20 (1H, broad, OH; disappeared on D_2O addition), 3.42 (2H, t, J=7 Hz, C-2-H), 3.77 (3H, s, OMe), 5.03 and 5.23 (2H, each m, CH_2–CH=C$\underline{H}_2$), 5.96 (1H, tdd, J=6, 9, 18 Hz, CH_2–C$\underline{H}$=CH_2), 6.53 (2H, m, Ar–H). Acetamide: MS *m/e*: 245 (M^+); IR $\nu_{max}^{CCl_4}$ cm^{-1}: 1660, 1150, 920; NMR δ: 1.90 (3H, s, NAc), 1.5—4.1 (6H, m, C-2-H+C-3-H+C-4-H), 3.33 (2H, m, C$\underline{H}_2$–CH=CH_2), 3.83 (3H, s, OMe), 4.97 and 5.03 (2H, each m, CH_2–CH= C$\underline{H}_2$), 5.90 (1H, m, CH_2–C$\underline{H}$=CH_2), 6.70 (2H, s, Ar–H).

Methylation of 19a——The amine **19a** (0.650 g, 3.8 mmol) and iodomethane (2.1 g) in acetone (15 ml) were refluxed for 6.5 h. Further MeI (1.0 g; total 3.1 g, 22 mmol) was added and refluxing was resumed for 14 h. The reaction mixture was cooled, inorganic material was removed, and the filtrate was evaporated to dryness. The residue was immersed in ether and the solution was extracted twice with 1 N HCl. Aqueous extracts were basified and extracted with ether to give 0.472 g (67%) of **15a**, which was identical with the specimen prepared from **14a** (TLC, GLC and IR spectroscopy). Ether-insoluble material (0.796 g) was washed with $CHCl_3$. The residue was recrystallized from CH_2Cl_2–acetone to give 8-allyl-1,1-dimethyl-1,2,3,4-tetrahydroquinolinium iodide **15a**: colorless plates, mp 150—150.5°C (dec.); IR ν_{max}^{KBr} cm^{-1}: 1633, 923; NMR δ: 2.35 (2H, m, C-3-H), 3.18 (2H, t, J=6.5 Hz, C-4-H), 3.83 (2H, d, J=5 Hz, CH_2–C$\underline{H}$=CH_2), 4.00 (6H, s, NMe_2), 4.42 (2H, t, J=5.5 Hz, C-2-H), 4.87, 5.17 and 5.33 (2H, each m, CH_2–CH=C$\underline{H}_2$), 6.05 (1H, m, CH_2–C$\underline{H}$=CH_2), 7.17 (3H, m, Ar–H). *Anal.* Calcd for $C_{14}H_{20}NI$: C, 51.08; H, 6.12; N, 4.26%. Found: C, 50.96; H, 6.11; N, 3.86%.

Methylation of 19b——The secondary amine **19b** (58 mg) was methylated with $NaBH_3CN$ (73 g, 1.2 mmol) and 37% HCHO (0.25 ml) in MeCN (2 ml), with addition of AcOH (0.1+0.1 ml). The product (56 mg, 94%) was identical with **15b** derived from **14b** (TLC and NMR spectroscopy).

1-Methyl-8-propyl-1,2,3,4-tetrahydroquinoline 24——a) 8-Allylkairoline **15a** was hydrogenated on 10% Pd-C in MeOH under hydrogen to give a liquid product, **24**: IR ν_{max}^{film} cm^{-1}: 2795, 1590; NMR δ: 0.98 (3H, t, J=6.5 Hz, CH_2–CH_2–Me), 1.38—2.02 (4H, m, CH_2–CH_2–Me+C-3-H), 4.35 (3H, s, NMe), 4.12—4.83 (6H, m, CH_2–Et+C-2-H+C-4-H), 6.72—7.02 (3H, m, Ar–H). Picrate: yellow rods, mp 143.5—147°C (EtOH). *Anal.* Calcd for $C_{19}H_{22}N_4O_7$: C, 54.54; H, 5.30; N, 13.39. Found: C, 54.52; H, 5.40; N, 13.38.

b) 4-Methyljulolidinium iodide **25** (469 mg, 1.5 mmol) and *t*-BuOK (746 mg, 6.6 mmol) in anhydrous *t*-BuOH (10 ml) were refluxed for 13 h under N_2. The crude product (226 mg) was catalytically hydrogenated over 10% Pd-C in MeOH to give a mixture of julolidine (59%) and 8-propylkairoline **24** (41%). Preparative GLC (20% SE-30) gave julolidine (47 mg) and **24** (29 mg), which was identical with the specimen obtained in reaction a).

Transformation of 6-Allyl-1,2,3,4-tetrahydroquinoline 20 into 9-Propyljulolidine 29——a) The secondary amine **20** (217 mg) was acetylated with a mixture of pyridine and Ac_2O (1/1, 2 ml) overnight. The crude product (196 mg) was purified by bulb-to-bulb distillation at 137°C/3 mmHg to give 82 mg of 1-acetyl-6-allyl-1,2,3,4-tetrahydroquinoline **26**: IR ν_{max}^{film} cm^{-1}: 1657, 1612, 1375; NMR δ: 1.93 (2H, m, C-3-H), 2.23 (3H, s, Ac), 2.72 (2H, t, J=6.5 Hz, C-4-H), 3.37 (2H, d, J=6 Hz, CH_2–CH=CH_2), 3.78 (2H, t, J=6 Hz, C-2-H), 4.96 and 5.20 (2H, each m, CH_2–CH=CH_2), 5.98 (1H, m, CH_2–CH=CH_2), 7.03 (3H, m, Ar–H). *Anal.* Calcd for $C_{14}H_{17}NO$: C, 78.10; H, 7.96; N, 6.51. Found: C, 77.93; H, 7.95; N, 6.28.

b) The olefinic amide **26** (288 mg) in EtOH (15 ml) was hydrogenated over 5% Pd-C (67 mg). Column chromatography (SiO_2 3.0 g, CH_2Cl_2) of the crude product (277 mg) gave 188 mg of 1-acetyl-6-propyl-1,2,3,4-tetrahydroquinoline **27**: MS *m/e*: 217 (M^+); IR ν_{max}^{film} cm^{-1}: 1660; NMR δ: 0.96 (3H, t, J=6.5 Hz, CH_2–CH_2–Me), 1.3—2.2 (4H, m, C-3-H+CH_2–CH_2–Me; signals appeared at δ 1.93, t, J=6 Hz, on irradiation at δ 3.77), 2.23 (3H, s, Ac), 2.57 (2H, t, J=7.5 Hz, Ar–CH_2–Et), 2.70 (2H, t, J=6.5 Hz, C-4-H), 3.77 (2H, t, J=6.5 Hz, C-2-H; singlet on irradiation at δ 1.93), 6.8—7.2 (3H, m, Ar–H).

c) The amide **27** (244 mg) was refluxed in 48% HBr (5 ml) for 3 h. The crude product (186 mg) was chromatographed on SiO_2 (3.5 g) with CH_2Cl_2–hexane (1/1) to give 6-propyl-1,2,3,4-tetrahydroquinoline **28**: IR ν_{max}^{film} cm^{-1}: 3420; NMR δ: 0.93 (3H, t, J=7 Hz, CH_2–CH_2–Me), 1.60 (2H, m, CH_2–CH_2–Me), 1.90 (2H, m, C-3-H), 2.46 (2H, t, J=6.5 Hz, Ar–CH_2–Et; singlet on irradiation at δ 1.60), 2.73 (2H, t, J=6 Hz, C-4-H), 3.27 (2H, t, J=5.5 Hz, C-2-H), 3.43 (1H, s, NH, disappeared on D_2O addition), 6.40 (1H, d, J=9 Hz, C-8-H), 6.83 (2H, m, Ar–H).

d) The secondary amine **28** (172 mg) in 1,3-bromochloropropane (15 ml) was refluxed for 22.5 h under N_2.[18] The dark red reaction mixture was strongly acidified with conc.HCl (2 ml), then steam-distilled. The residual green solution was washed once with ether, then basified with Na_2CO_3. Extraction with ether three times yielded a brown liquid (169 mg) which was purified by column chromatography (SiO_2 4.0 g, CH_2Cl_2–hexane=1/1) to give 152 mg of 9-propyljulolidine **29**: MS *m/e*: 215 (M^+); IR ν_{max}^{film} cm^{-1}: 2780, 1610, 1500, 1305; NMR δ: 0.92 (3H, t, J=7 Hz, CH_2–CH_2–Me), 1.58 (2H, m, CH_2–CH_2–Me), 1.97 (4H, m, C-2-H+C-6-H), 2.41 (2H, t, J=7.5 Hz, Ar–CH_2–Et; singlet on irradiation at δ 1.58), 2.73 (4H, t, J=6 Hz, C-1-H+C-7-H; singlet on irradiation at δ 1.97), 3.10 (4H, t, J=5.5 Hz, C-3-H+C-5-H), 6.65 (2H, s, Ar–H). Picrate: yellow leaflets, mp 129—134°C (EtOH). *Anal.* Calcd for $C_{21}H_{24}N_4O_7$: C, 56.75; H, 5.44; n, 12.61%. Found: C, 56.46; H, 5.37; N, 12.47%.

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