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Reactions of Bi-, Tri-, and Tetracyclic Amines with Succinic Anhydride

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Abstract—Succinic anhydride reacted with cage-like amines {bicyclo[2.2.1]hept-5-en-*exo*- and -*endo*-2-ylmethanamines, 2-(bicyclo[2.2.1]hept-5-en-*endo*-2-yl)ethanamine, *exo*-5,6-epoxybicyclo[2.2.1]heptan-*exo*-2-ylmethanamine, tetracyclo[6.2.1.1^{3,6}.0^{2,7}]dodec-9-en-*endo*-4-ylmethanamine, 1-(bicyclo[2.2.1]heptan-2-yl)ethanamine, and 4-azatricyclo[5.2.1.0^{2,6}]dec-8-ene} to give the corresponding amido acids having a cage-like fragment. The latter were converted into carboximides by the action of hexamethyldisilazane in boiling benzene in the presence of zinc(II) chloride and then into epoxy derivatives. The structure of the newly synthesized compounds was confirmed by IR and NMR spectroscopy.

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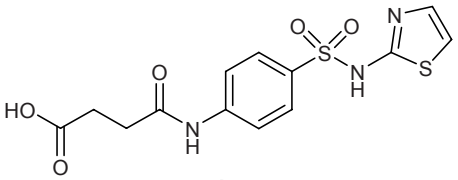
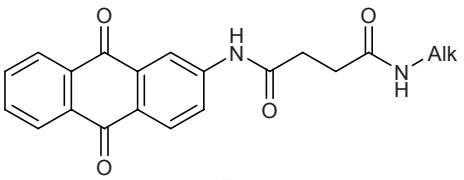
Successful attempts to use succinic, maleic, phthalic, and other dicarboxylic acid anhydrides for the design of medical agents are well known [1, 2]. Substituted 1,4-dicarboxamides exhibit antiphlogistic, hemostatic, anticoagulant, and antiatherosclerotic activity [3]. Succinylsulfothiazole **Ia** [1] and other antimicrobial [4], antiviral, antiarrhythmic, and antiaggregation agents, as well as compounds possessing pronounced neurotropic activity [5], were synthesized on the basis of 1,4-dicarboxamides. *N*-Pyridyl and other succinamides were found to exhibit hypertensive and hypoglycemic activity [6]. *N*,*N*′-Substituted succinamides **Ib** induce liver cytochrome P-450 system and act as antioxidant and membrane-stabilizing agents [7]. Succinimides, e.g., Ethosuximide (**Ic**) and Pufemide, are used in the treatment of mild epilepsy; they inhibit motor centers in the cortex of cerebral hemispheres and enhance myoclonic threshold [1].

The present study was stimulated by the results of using cage-like amines in the development of new anti-HIV agents which reduce viral load in patients and inhibit progress of the disease [8, 9]. Anti-HIV drugs of new generation were obtained from polymerized maleic anhydride and pharmacophoric amines which were linked to a water-soluble polyanionic matrix through various spacers (CH_2, CH_2CH_2, etc.). Insofar as the above approach utilized amines having norbornene, norbornane, and tri- and tetracyclic fragments, the goal of the present study was formulated as synthesis of monomeric analogs of the polymeric systems, namely products of reactions of succinic anhydride with cage-like amines **II**–**VIII** having bi-, tri-, and tetracyclic skeletons.

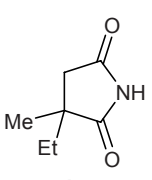
The key issue in the synthesis of stereochemically homogeneous *exo*- (**II**) and *endo*-isomeric (**IV**) amines of the norbornene series was isolation of pure *exo*- and *endo*-nitriles **IXa** and **IXb** formed by the Diels–Alder reaction of cyclopentadiene with acrylonitrile [10] (Scheme 1). Epoxy nitrile **IXc** was synthesized by oxidation of nitrile **IXa** with peroxyphthalic acid



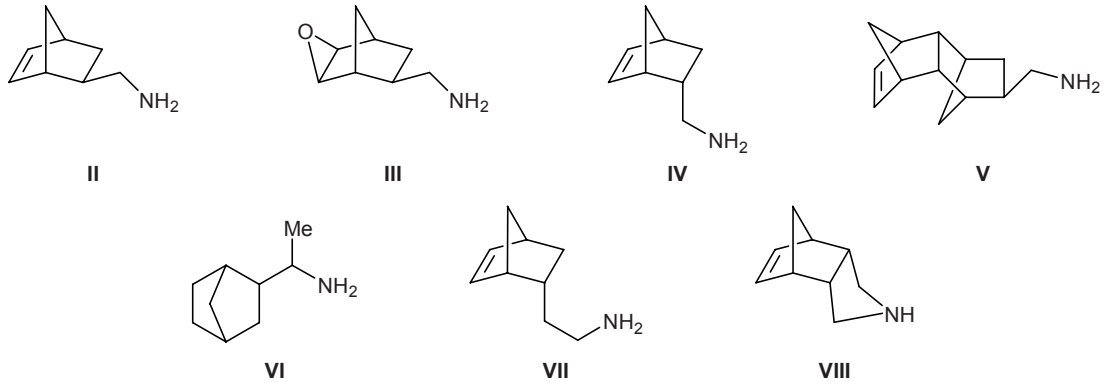
Ia



Ib



Ic

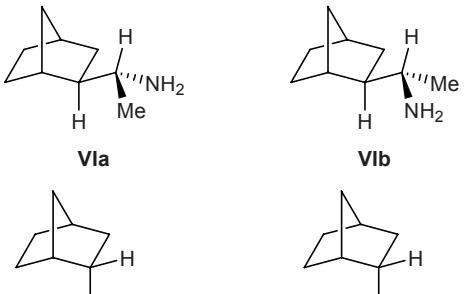


II **III** **IV** **V**

VI **VII** **VIII**

($ArCO_3H$) generated *in situ* from phthalic anhydride and 30% aqueous hydrogen peroxide [11]. Tetracyclic nitrile **IXd** was obtained by the Diels–Alder reaction of *endo*-nitrile **IXb** with cyclopentadiene in a metal reactor at 170–175°C (10 h). Quantum-chemical analysis [B3LYP/6-31G(*d*)] of the potential energy surface of this reaction [12] showed that *endo*,*exo*-junction of the bicyclic fragments and *anti*-orientation of the methylene bridges in the tetracyclic skeleton of nitrile **IXd** are preferred. Nitriles **IXa**–**IXd** were reduced to amines **II**–**V** with lithium aluminum hydride in boiling diethyl ether; nitrile **IXc** reacted in a chemoselective fashion with conservation of the oxirane ring, in keeping with our previous data [13].

1-(Bicyclo[2.2.1]hept-2-il)ethanamine (**VI**) was obtained as a mixture of diastereoisomers **VIa**–**VId** from the known antiviral agent Deitiforin hydrochloride [1].



VIa **VIb**

VIc **VId**

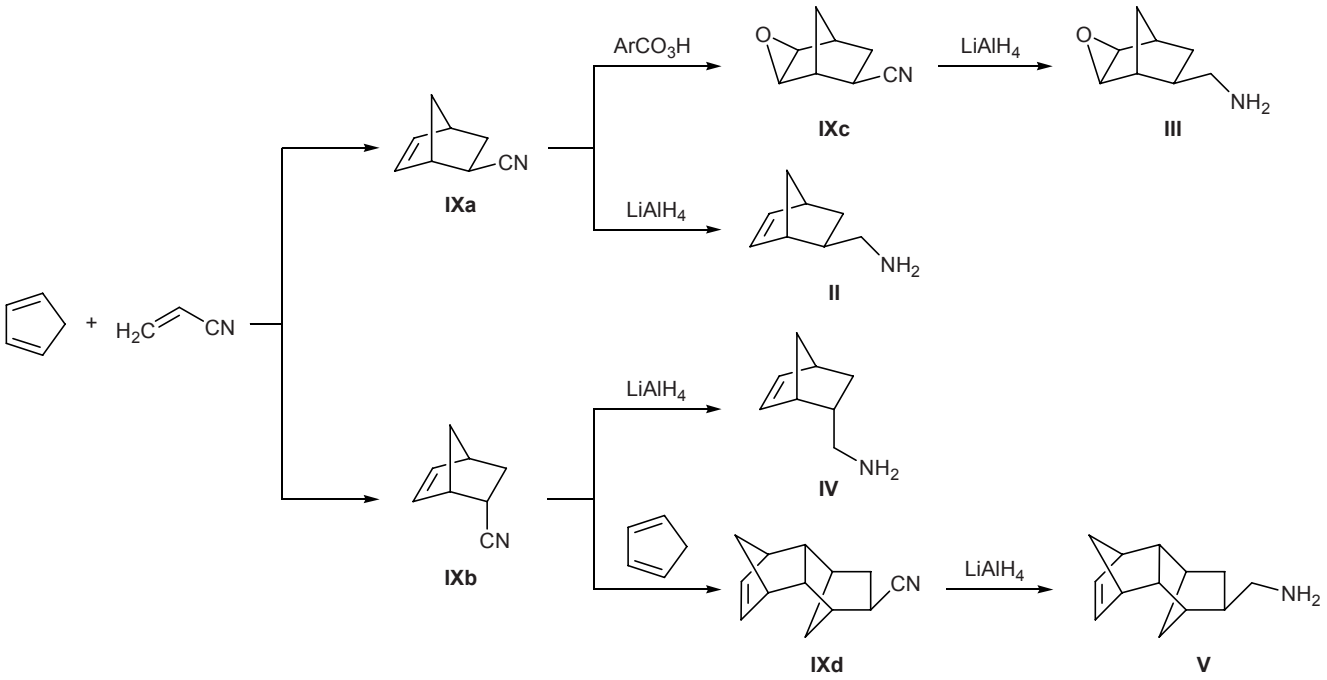
Amine **VII** [14] was synthesized according to modified procedure [15] from the cyclopentadiene adduct with acrolein. Secondary tricyclic amine **VIII** with *endo*-orientation of the substituent was prepared by reduction of bicyclo[2.2.1]hept-5-ene-*endo*-2,3-dicarboximide (**IXe**) with lithium tetrahydridoaluminate [16] (Scheme 2).

In most cases, reactions of amines with dicarboxylic acid anhydrides were carried out in benzene in the cold. Following this procedure, 1,4,5,6,7,7-hexachlorobicyclo[2.2.1]hept-5-en-2-ylmethanamine reacted with maleic anhydride to give a product which showed fungicidal activity [17]. Analogous conditions were successfully reproduced in other studies on cage-like amines [18]; however, they turned out to be inappropriate for the reactions with succinic anhydride because of its poor solubility in benzene at room temperature. Therefore, the acylation of cage-like amines with succinic anhydride was performed in ethyl acetate by heating for a short time to 50°C, and the products crystallized from the reaction mixtures on cooling (Scheme 3). The purity of the products and reaction completion were monitored by thin-layer chromatography. Analysis of the IR and ^1H NMR spectral data allowed us to assign amido acid structures **X**–**XVI** to the acylation products.

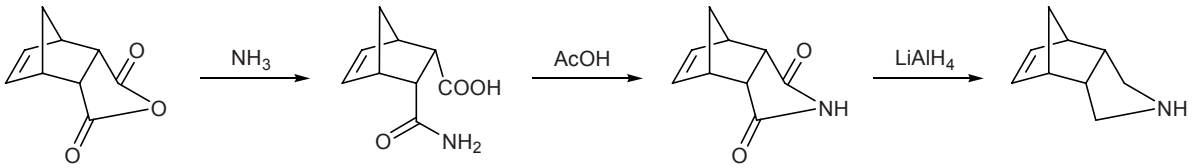
The IR spectra of **X**–**XVI** contained absorption bands assignable to the amide group at 1640–1620 (ν C=O), 1550–1535 (δ N–H), and 1290–1270 cm^{-1} (ν C–N) [19]. The second band was absent in the IR spectrum of tertiary amide **XVI**. Absorption in the region 3400–3200 cm^{-1} was attributed to stretching vibrations of O–H and N–H groups. Compound **XVI** showed in the IR spectrum only one band in the above region (3421 cm^{-1}). The acid carbonyl group gave rise to absorption at 1720–1705 cm^{-1}. Unsaturated fragment in the strained norbornene skeleton was characterized by absorption bands in the regions 3070–3050 (ν C–H) and 730–720 cm^{-1} (δ C–H) [20]. In the IR spectrum of epoxide **XI** we observed an absorption band at 855–850 cm^{-1}, which belongs to stretching vibrations of the oxirane C–O bonds [11, 21].

Complex ^1H NMR spectra of amido acids **X**–**XVI** were interpreted using the corresponding data for parent amines. The spectra of **X**–**XVI** contained two new signals, an unresolved four-proton multiplet at δ 2.21–2.28 ppm (CH_2CH_2) and a diffuse signal at δ 7.60–7.70 ppm (exchangeable protons of the carboxy

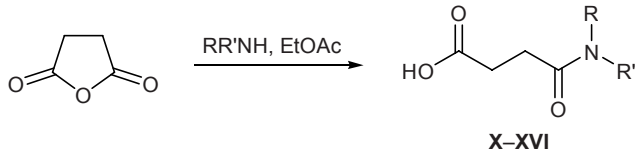
Scheme 1.

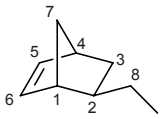
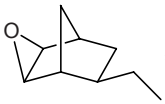
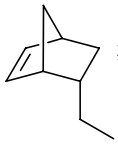
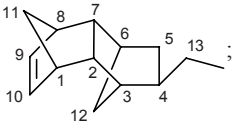


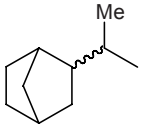
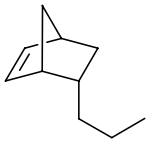
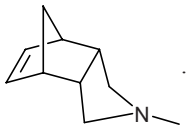
Scheme 2.



Scheme 3.



X–**XV**, R = H; **X**, R′ =  ; **XI**, R′ =  ; **XII**, R′ =  ; **XIII**, R′ =  ;

XIV, R′ =  ; **XV**, R′ =  ; **XVI**, RR′N =  .

and amide NH groups). Signals from the 2-H and 8-H protons (that are neighboring to the carbonyl group) in the spectra of bicyclic amido acids were displaced considerably downfield relative to their positions in the spectra of the initial amines. Comparison of the ^{1}H NMR spectra of *exo* and *endo* stereoisomers **X** and **XII**, as well as of compound **XV** with *endo* orientation of the aminoethyl group, showed a rigorous dependence of the spectral pattern on the stereochemical structure of the norbornene fragment. Therefore, we were able to use criteria which were formulated previously while interpreting the ^{1}H NMR spectra of

stereoisomeric amines **II** and **IV** and their derivatives, such as sulfonamides, carboxamides, ureas, and amino alcohols [22]. The spectrum of *exo* isomer **X** is characterized by a slight nonequivalence of 5-H/6-H ($\Delta\delta$ = 0.05 ppm) and *exo*-3-H/*endo*-3-H ($\Delta\delta$ = 0.09 ppm) and stronger nonequivalence of 1-H/4-H ($\Delta\delta$ = 0.13 ppm). The corresponding $\Delta\delta$ values for *endo*-isomeric amido acid **XII** are 0.21, 1.30, and 0.10 ppm, respectively, and for *endo* isomer **XV**, 0.20, 1.37, and 0.04 ppm. These data confirm the assumed structure of stereoisomers **X** and **XII** and demonstrate applicability of the previously developed criteria to assignment of the new norbornene derivatives to the *exo* or *endo* series on the basis of their ^{1}H NMR spectra.

Variation of the ^{1}H NMR spectral pattern in going from unsaturated compound **X** to epoxynorbornane derivative **XI** should be noted. The 5-H and 6-H signals in the spectrum of **XI** are displaced to δ 3.12 and 3.05 ppm [11, 22], and the *anti*-7-H signal appears at δ 0.76 ppm due to magnetically anisotropic effect of the *exo*-oriented epoxide ring on the proton in the methylene bridge located directly above the oxirane ring plane. The observed shift of the *anti*-7-H signal provides a convincing proof for the *exo* orientation of the epoxide ring in the epoxynorbornane series [23].

The mechanism of aminolysis of dicarboxylic acid anhydrides is not completely understood even for their reactions with aliphatic and aromatic amines [24, 25]. Analysis of the potential energy surface simulated at the B3LYP/6-31G* level for the reaction of succinic anhydride with methylamine revealed greater probability for the reaction to follow concerted (S_N2) mechanism rather than consecutive addition–elimination path; the calculations also showed efficiency of the second amine molecule as difunctional catalyst.

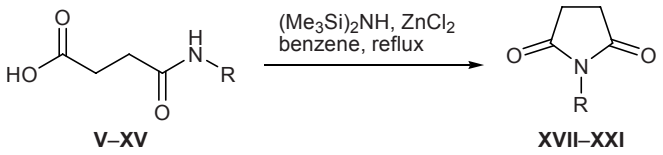
Amido acids **XI**–**XVI** were converted into the corresponding dicarboximides. Initially, the dehydration of **XII** was performed according to the procedure proposed previously for amido acids derived from endic anhydride, i.e., by heating the substrate in boiling glacial acetic acid. However, the reaction was accompanied by tarring. Therefore, we tried a different method [26] implying treatment of amido acids with hexamethyldisilazane in boiling benzene in the presence of zinc(II) chloride. Presumably, the reaction involves intermediate formation of the corresponding trimethylsilyl esters which then undergo thermal dehydration with formation of imides **XVII**–**XXI** and hexamethyldisiloxane (Scheme 4).

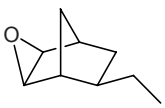
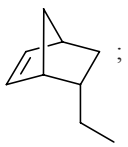
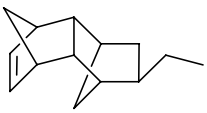
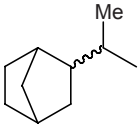
The IR spectra of imides **XVII**–**XXI** lacked absorption in the regions 3400–3300 and 1580–1540 cm^{-1} typical of NH and OH groups, and no amide I band was observed. Stretching vibrations of the imide carbonyl groups appeared in the frequency region 1735–1690 cm^{-1}. Unsaturated compounds **XVIII**, **XIX**, and **XXI** displayed absorption bands due to stretching and bending vibrations of C–H bonds at the strained double C=C bond (3073–3070 and 732–730 cm^{-1}, respectively) [20]. The presence of an absorption band at 850 cm^{-1} in the IR spectrum of compound **XVII** indicated conservation of the epoxynorbornane fragment, which is inactive in the absence of strong acids.

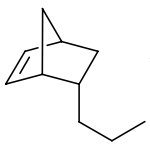
The ^{1}H NMR spectra of compounds **XVIII** and **XXI** showed some differences in proton shielding as compared to initial amido acids **XII** and **XV**. The presence of two spatially close carbonyl groups in molecule **XVIII** induces a considerable downfield shift of the 8-H_A and 8-H_B signals (δ 3.10 and 3.01 ppm, respectively) relative to their positions in the spectrum of acid **XII** (δ 2.49 and 2.42 ppm). A smaller shift was observed for the 9-H_A and 9-H_B signals in the spectrum of **XXI** compared to **XV**. In the ^{1}H NMR spectra of **XXI** and **XV**, the *endo*-3-H protons are characterized by the lowest chemical shifts (δ 0.45 and 0.49 ppm), indicating stronger anisotropic effect of the $C^2C^8C^9$ fragment than that produced by the C^2–C^8 bond.

Epoxides **XXII** and **XXIII** were synthesized by an alternative method, oxidation of imides **XVIII** and

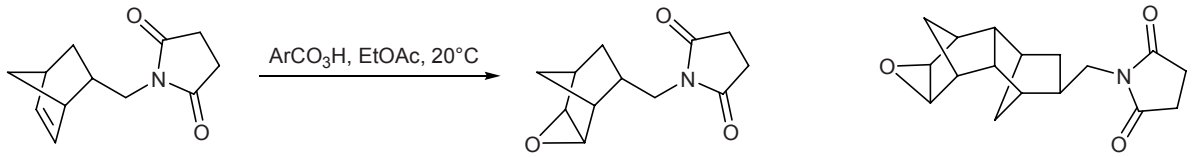
Scheme 4.



XVII, R =  ; **XVIII**, R =  ; **XIX**, R =  ; **XX**, R = 

; **XXI**, R =  .

Scheme 5.



XVIII **XXII** **XXIII**

XIX, respectively, with peroxyphthalic acid generated *in situ* from phthalic anhydride and 30% hydrogen peroxide in ethyl acetate in the presence of urea (the latter was added to control proton-donor/acceptor power of the reaction medium) [11, 27]. The IR spectrum of epoxy imide **XXII** contained no absorption typical of unsaturated fragment, the epoxide ring gave rise to absorption at 841 cm^{-1}, and stretching vibration bands of the imide carbonyl groups appeared at 1781 and 1719 cm^{-1} [18].

EXPERIMENTAL

The IR spectra were recorded on a Specord 75IR spectrometer from samples prepared as thin films or KBr pellets. The ^1H NMR spectra were measured on a Varian VXR spectrometer operating at 300 MHz; chloroform-*d* and DMSO-d_6 were used as solvents, and tetramethylsilane, as internal reference. The progress of reactions and the purity of products were monitored by TLC on Silufol UV-254 plates using diethyl ether as eluent; spots were visualized by treatment with iodine vapor. The elemental compositions were determined on a Carlo Erba analyzer.

4-(Bicyclo[2.2.1]hept-5-en-*exo*-2-ylmethylamino)-4-oxobutanoic acid (X). A solution of 0.20 g (0.002 mol) of succinic anhydride in ethyl acetate was added under stirring to a solution of 0.25 g (0.002 mol) of amine **II** in 5 ml of ethyl acetate. The mixture was quickly heated to 50°C and cooled, and the precipitate was filtered off, washed with ethyl acetate, and recrystallized from the same solvent. Yield 78%, mp 96–97°C, R_f 0.18. IR spectrum, ν, cm^{-1}: 3430, 3271, 3052, 1705, 1644, 1550, 1295, 720. ^1H NMR spectrum, δ, ppm: 1.17 m (1H, *endo*-3-H), 1.20 d.d (1H, *syn*-7-H), 1.25 d (1H, *anti*-7-H), 1.26 m (1H, *exo*-3-H), 1.56 m (1H, 2-H), 2.20 s (4H, CH_2CH_2), 2.70 m (1H, 1-H), 2.75 d.d (1H, 8-H_B), 2.79 d.d (1H, 8-H_A), 2.83 m (1H, 4-H), 6.03 d.d (1H, 6-H), 6.08 d.d (1H, 5-H), 7.60 br.s (1H, NH). Found, %: C 64.47; H 6.31. $C_{12}H_{17}NO_3$. Calculated, %: C 64.57; H 6.28.

4-(*exo*-5,6-Epoxybicyclo[2.2.1]heptan-*exo*-2-ylmethylamino)-4-oxobutanoic acid (XI) was synthesized in a similar way from amine **III**. Yield 63%, mp 132–133°C, R_f 0.19. IR spectrum, ν, cm^{-1}: 3510, 3251, 3025, 1720, 1645, 1541, 1290, 855. ^1H NMR spectrum, δ, ppm: 0.76 d (1H, *anti*-7-H), 1.02 m (1H, *endo*-3-H, $^4J_{endo\text{-}3,syn\text{-}7}$ = 4.0 Hz), 1.07 d.d (1H, *syn*-7-H, ^2J = 10.2 Hz), 1.38 m (1H, *exo*-3-H, ^2J = 10.1 Hz), 1.62 m (1H, 2-H), 2.28 s (4H, CH_2CH_2), 2.34 d.d (1H, 8-H_B), 2.39 d.d (1H, 8-H_A), 2.57 m (1H, 1-H), 2.60 m (1H, 4-H), 3.05 d.d (1H, 6-H), 3.12 d.d (1H, 5-H, $^3J_{5,6}$ = 4.1 Hz), 6.70 br.s (1H, NH). Found, %: C 60.34; H 5.91. $C_{12}H_{17}NO_4$. Calculated, %: C 60.25; H 5.86.

4-(Bicyclo[2.2.1]hept-5-en-*endo*-2-ylmethylamino)-4-oxobutanoic acid (XII) was synthesized in a similar way from amine **IV**. Yield 58%, mp 102–103°C, R_f 0.16. IR spectrum, ν, cm^{-1}: 3415, 3261, 3066, 1711, 1645, 1548, 1280, 731. ^1H NMR spectrum, δ, ppm: 0.53 m (1H, *endo*-3-H, $^3J_{endo\text{-}3,2}$ = 4.0, $^4J_{endo\text{-}3,syn\text{-}7}$ = 2.6 Hz), 1.22 d (1H, *anti*-7-H), 1.35 d.d (1H, *syn*-7-H, ^2J = 8.4 Hz), 1.83 m (1H, *exo*-3-H, ^2J = 11.8, $^3J_{exo\text{-}3,2}$ = 7.9, $^3J_{exo\text{-}3,4}$ = 3.2 Hz), 2.19 m (1H, 2-H), 2.21 s (4H, CH_2CH_2), 2.42 d.d (1H, 8-H_B), 2.49 d.d (1H, 8-H_A), 2.78 m (1H, 1-H), 2.88 m (1H, 4-H), 5.97 d.d (1H, 6-H, $^3J_{6,1}$ = 3.0 Hz), 6.10 d.d (1H, 5-H, $^3J_{5,6}$ = 5.8, $^3J_{5,4}$ = 2.8 Hz), 7.60 br.s (1H, NH). Found, %: C 64.70; H 6.38. $C_{12}H_{17}NO_3$. Calculated, %: C 64.57; H 6.28.

4-(Tetracyclo[6.2.1^{3,6}.0^{2,7}]dodec-9-en-*endo*-4-ylmethylamino)-4-oxobutanoic acid (XIII) was synthesized in a similar way from amine **V**. Yield 76%, mp 159–160°C, R_f 0.13. IR spectrum, ν, cm^{-1}: 3395, 3190, 3055, 1710, 1621, 1535, 1290, 750. ^1H NMR spectrum, δ, ppm: 0.47 m (1H, *endo*-5-H, $^3J_{endo\text{-}5,4}$ = 4.9, $^4J_{endo\text{-}5,syn\text{-}12}$ = 2.5 Hz), 0.54 d (1H, *anti*-12-H), 1.11 d (1H, *anti*-11-H), 1.14 d (1H, *syn*-11-H, ^2J = 7.8 Hz), 1.61 m (1H, *exo*-5-H, ^2J = 11.3, $^3J_{exo\text{-}5,4}$ = 4.7, $^3J_{exo\text{-}5,6}$ = 4.7 Hz), 1.84 d.d (1H, 7-H, $^3J_{7,8}$ = 3.8 Hz), 1.93 m (1H, 3-H), 2.04 m (1H, 6-H), 2.08 d.d (1H, 2-H, $^3J_{2,7}$ = 8.4, $^3J_{2,1}$ = 4.1 Hz), 2.10 d.d (1H, *syn*-12-H, ^2J = 10.2 Hz), 2.12 m (1H, 4-H), 2.30 s (4H, CH_2CH_2), 2.74 m (1H, 8-H), 2.81 m (1H, 1-H), 3.96 d.d (1H, 13-H_B), 3.98 d.d (1H, 13-H_A), 5.89 d.d (1H, 10-H, $^3J_{10,7}$ = 3.4 Hz), 5.97 d.d (1H, 9-H, $^3J_{9,10}$ =

5.6, $^3J_{9,8}$ = 3.2 Hz). Found, %: C 70.71; H 4.87. $C_{17}H_{23}NO_3$. Calculated, %: C 70.59; H 4.84.

4-[1-(Bicyclo[2.2.1]hept-2-yl)ethylamino]-4-oxobutanoic acid (XIV) was synthesized in a similar way from amine **VI**. Yield 58%, mp 79–81°C, R_f 0 (the spot remained at the start). IR spectrum, ν, cm^{-1}: 3300, 1713, 1645, 1539, 1275. Found, %: C 67.09; H 5.83. $C_{13}H_{21}NO_3$. Calculated, %: C 67.27; H 5.86.

4-[2-(Bicyclo[2.2.1]hept-5-en-*endo*-2-yl)ethylamino]-4-oxobutanoic acid (XV) was synthesized in a similar way from amine **VII**. Yield 44%, mp 123–124°C, R_f 0.22. IR spectrum, ν, cm^{-1}: 3342, 3255, 3061, 1705, 1608, 1541, 1292, 730. ^{1}H NMR spectrum, δ, ppm: 0.49 m (1H, *endo*-3-H, $^3J_{endo\text{-}3,2}$ = 3.6, $^4J_{endo\text{-}3,syn\text{-}7}$ = 2.8 Hz), 1.22 d (1H, *anti*-7-H), 1.26 d.d (1H, 8-H_B), 1.33 d.d (1H, 8-H_A, ^2J = 11.2 Hz), 1.37 d.d (1H, *syn*-7-H, ^2J = 8.1 Hz), 1.86 m (1H, *exo*-3-H, ^2J = 11.0, $^3J_{exo\text{-}3,2}$ = 9.1, $^3J_{exo\text{-}3,4}$ = 3.5 Hz), 2.01 m (1H, 2-H), 2.28 s (4H, CH_2CH_2), 2.68 m (1H, 1-H), 2.70 m (1H, 9-H_B), 2.72 m (1H, 4-H), 2.77 m (1H, 9-H_A, ^2J = 14.3, $^3J_{9A,8}$ = 7.0 Hz), 5.93 d.d (1H, 6-H, $^3J_{6,1}$ = 3.0 Hz), 6.13 d.d (1H, 5-H, $^3J_{5,6}$ = 5.4, $^3J_{5,4}$ = 2.7 Hz), 7.60 br.s (1H, NH). Found, %: C 66.00; H 6.03. $C_{13}H_{19}NO_3$. Calculated, %: C 65.82; H 5.91.

4-(4-Azatricyclo[5.2.1.$0^{2,6}$]dec-8-en-*endo*-4-yl)-4-oxobutanoic acid (XVI) was synthesized in a similar way from amine **VIII**. Yield 57%, oily substance, R_f 0.24. IR spectrum, ν, cm^{-1}: 3421, 3071, 1715, 1641, 1285, 730. Found, %: C 66.50; H 5.85. $C_{13}H_{17}NO_3$. Calculated, %: C 66.38; H 5.96.

***N*-(*exo*-5,6-Epoxybicyclo[2.2.1]hept-*exo*-2-ylmethyl)succinimide (XVII).** A solution of 0.24 g (0.32 ml, 0.0015 mol) of hexamethyldisilazane in 5 ml of anhydrous benzene was added dropwise under stirring to a mixture of 0.24 g (0.001 mol) of amido acid **XI** and 0.13 g (0.001 mol) of anhydrous zinc(II) chloride in anhydrous benzene, heated to 60°C. The mixture was heated for 3 h at that temperature, cooled, and treated with 20 ml of a 1% aqueous solution of sodium hydroxide. The organic layer was separated, the aqueous phase was extracted with ethyl acetate, the extracts were combined with the organic phase and dried, the solvent was evaporated, and the residue was purified by recrystallization from benzene–hexane. Yield 48%, mp 179–181°C, R_f 0.29. IR spectrum, ν, cm^{-1}: 3031, 1730, 1700, 1420, 1205, 850. Found, %: C 64.98; H 6.24. $C_{12}H_{15}NO_3$. Calculated, %: C 65.16; H 6.33.

***N*-(Bicyclo[2.2.1]hept-5-en-*endo*-2-ylmethyl)succinimide (XVIII)** was synthesized in a similar way from amido acid **XII**. Yield 43%, mp 173–174°C, R_f 0.33. IR spectrum, ν, cm^{-1}: 3070, 1720, 1690, 1414, 1200, 730. ^{1}H NMR spectrum, δ, ppm: 0.52 m (1H, *endo*-3-H, $^3J_{endo\text{-}3,2}$ = 4.8, $^4J_{endo\text{-}3,syn\text{-}7}$ = 2.4 Hz), 1.16 d (1H, *anti*-7-H), 1.29 d.d (1H, *syn*-7-H, ^2J = 7.5 Hz), 1.79 m (1H, *exo*-3-H, ^2J = 11.4, $^3J_{exo\text{-}3,2}$ = 8.1, $^3J_{exo\text{-}3,4}$ = 3.6 Hz), 2.14 m (1H, 2-H), 2.31 s (4H, CH_2CH_2), 2.75 m (1H, 1-H), 2.90 m (1H, 4-H), 3.01 d.d (1H, 8-H_B), 3.10 d.d (1H, 8-H_A, ^2J = 14.0 Hz), 6.01 d.d (1H, 6-H, $^3J_{6,1}$ = 3.0 Hz), 6.20 d.d (1H, 5-H, $^3J_{5,6}$ = 5.7, $^3J_{5,4}$ = 3.0 Hz). Found, %: C 70.09; H 6.75. $C_{12}H_{15}NO_2$. Calculated, %: C 70.24; H 6.83.

***N*-(Tetracyclo[6.2.1^{3,6}.0^{2,7}]dodec-9-en-*endo*-4-ylmethyl)succinimide (XIX).** Yield 63%, mp 182–183°C, R_f 0.40. IR spectrum, ν, cm^{-1}: 3072, 1751, 1710, 1421, 730. ^{1}H NMR spectrum, δ, ppm: 0.53 m (1H, *endo*-5-H, $^3J_{endo\text{-}5,4}$ = 5.0, $^4J_{endo\text{-}5,syn\text{-}12}$ = 2.7 Hz), 0.59 d (1H, *anti*-12-H), 1.16 d (1H, *anti*-11-H), 1.66 m (1H, *exo*-5-H, ^2J = 11.7, $^3J_{exo\text{-}5,4}$ = 4.6, $^3J_{exo\text{-}5,6}$ = 4.6 Hz), 1.81 m (1H, *syn*-11-H, ^2J = 7.7 Hz), 1.89 d.d.d (1H, 7-H, $^3J_{7,8}$ = 3.6 Hz), 1.94 m (1H, 3-H), 2.10 m (1H, 2-H, $^3J_{2,7}$ = 8.2, $^3J_{2,1}$ = 4.1 Hz), 2.11 d.d (1H, *syn*-12-H, ^2J = 10.2 Hz), 2.16 m (2H, 4-H, 6-H), 2.30–2.35 m (4H, CH_2CH_2), 2.79 m (1H, 8-H), 2.81 m (1H, 1-H), 2.83 d.d (1H, 13-H_B), 2.92 d.d (1H, 13-H_A), 5.95 d.d (1H, 10-H, $^3J_{10,7}$ = 3.4 Hz), 6.03 d.d (1H, 9-H, $^3J_{9,10}$ = 5.6, $^3J_{9,8}$ = 3.2 Hz). Found, %: C 75.44; H 5.11. $C_{17}H_{21}NO_2$. Calculated, %: C 75.28; H 5.17.

***N*-[1-(Bicyclo[2.2.1]hept-*endo*-2-yl)ethyl]succinimide (XX).** Yield 74%, oily substance, R_f 0.48. IR spectrum, ν, cm^{-1}: 1726, 1699, 1420. Found, %: C 70.70; H 6.45. $C_{13}H_{19}NO_2$. Calculated, %: C 70.59; H 6.33.

***N*-[2-(Bicyclo[2.2.1]hept-5-en-*endo*-2-yl)ethyl]-succinimide (XXI).** Yield 52%, oily substance, R_f 0.53. IR spectrum, ν, cm^{-1}: 3073, 1723, 1698, 1418, 1211, 732. ^{1}H NMR spectrum, δ, ppm: 0.45 m (1H, *endo*-3-H, $^3J_{endo\text{-}3,2}$ = 4.2, $^4J_{endo\text{-}3,syn\text{-}7}$ = 2.4 Hz), 1.16 d (1H, *anti*-7-H), 1.23 m (1H, 8-H_B), 1.27 m (1H, 8-H_A), 1.29 d.d (1H, *syn*-7-H, ^2J = 8.1 Hz), 1.86 m (1H, *exo*-3-H, ^2J = 10.8, $^3J_{exo\text{-}3,2}$ = 7.8, $^3J_{exo\text{-}3,4}$ = 3.9 Hz), 2.00 m (1H, 2-H), 2.35 s (4H, CH_2CH_2), 2.60 m (1H, 1-H), 2.70 m (1H, 9-H_A), 2.76 m (1H, 4-H), 2.90 m (1H, 9-H_B), 5.95 d.d (1H, 6-H, $^3J_{6,1}$ = 3.0 Hz), 6.16 d.d (1H, 5-H, $^3J_{5,6}$ = 5.7, $^3J_{5,4}$ = 3.0 Hz), Found, %: C 71.04; H 6.31. $C_{13}H_{17}NO_2$. Calculated, %: C 71.23; H 6.39.

***N*-(*exo*-5,6-Epoxybicyclo[2.2.1]hept-*endo*-2-ylmethyl)succinimide (XXII).** Hydrogen peroxide (50% aqueous solution), 0.20 g (0.17 ml, 0.003 mol),

was added dropwise under stirring to a mixture of 0.20 g (0.001 mol) of imide **XVIII**, 0.30 g (0.002 mol) of phthalic anhydride, and 0.03 g (0.0005 mol) of urea in 50 ml of ethyl acetate. The mixture was stirred at room temperature until the reaction was complete (according to the TLC data) and neutralized with a saturated solution of sodium hydrogen carbonate, the organic layer was separated and dried over calcined magnesium sulfate, and the solvent was removed. Yield 62%, mp 161–162°C, R_f 0.37. IR spectrum, ν, cm^{-1}: 1781, 1719, 1420, 841. Found, %: C 65.32; H 6.24. $C_{12}H_{15}NO_3$. Calculated, %: C 65.16; H 6.33.

***N*-(*exo*-9,10-Epoxytetracyclo[6.2.1^{3,6}.0^{2,7}]dodec-*endo*-4-ylmethyl)succinimide (XXIII)** was synthesized in a similar way from imide **XIX**. Yield 43%, oily substance, R_f 0.28. ^{1}H NMR spectrum, δ, ppm: 0.56 m (1H, *endo*-5-H, $^3J_{endo\text{-}5,4}$ = 5.0 Hz), 0.58 m (1H, *anti*-11-H), 1.01 d (1H, *anti*-12-H), 1.22 m (1H, *syn*-11-H, ^2J = 7.8 Hz), 1.68 m (1H, *exo*-5-H, ^2J = 11.7, $^3J_{exo\text{-}5,4}$ = $^3J_{exo\text{-}5,6}$ = 4.2 Hz), 1.79 m (1H, 7-H), 1.96 d.d (1H, *syn*-12-H, ^2J = 10.2 Hz), 2.10 m (1H, 4-H), 2.15 m (1H, 3-H), 2.30–2.35 m (4H, CH_2CH_2), 2.36 s (1H, 6-H), 2.75 m (2H, 8-H, 10-H), 2.76 m (1H, 1-H), 2.78 m (1H, 9-H), 3.62 d.d (1H, 13-H$_B$, $^3J_{13B,4}$ = 6.6 Hz), 3.69 d.d (1H, 13-H$_A$, ^2J = 13.2, $^3J_{13A,4}$ = 5.6 Hz). Found, %: C 69.96; H 4.95. $C_{17}H_{21}NO_3$. Calculated, %: C 70.08; H 4.88.

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