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Synthetic Transformations of Higher Terpenoids: VIII.* [4 + 2]-Cycloaddition Reactions of Lambertianic Acid

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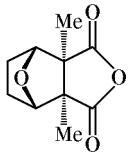
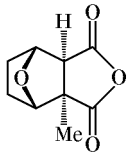
Abstract—The Diels–Alder reaction of lambertianic acid with maleic anhydride occurred in a stereoselective fashion and yielded diastereoisomeric (1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-*exo*-adducts. The latter reacted with L-valinol to give the corresponding diterpenoid imides, 4-aza-9-oxabicyclo[2.2.1]dec-8-enes. Reactions of lambertianic acid with N-substituted maleimides in the presence of Lewis acids afforded diastereoisomeric adducts having both *exo* and *endo* configuration. Some transformations of the adducts were examined with a view to obtain cantharidin and dihydroisoindole analogs.

Among Arthropoda toxins of nonprotein origin, cantharidin (**A**) produced by *Meloidae* blister beetles and *Cantharis vesicatoria* Spanish flies [2] attracts interest. This compound, as well as its monomethyl analog, (–)-palasonin (**B**) [3], exhibits antitumor activity [4]. Nitrogen-containing cantharidin analogs, N-substituted imides **C** and **D**, also attract attention due to their lower toxicity and wide spectrum of pharmacological activity [5–7].



A



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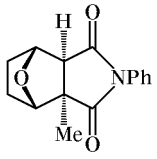

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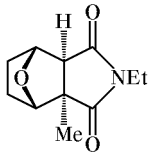

D

The unique anticarcinogenic properties of the above compounds have stimulated studies in the field of synthesis of their less toxic analogs. The synthetic approach to such structures is based on the cycloaddition of furan to various dienophiles [3, 6, 8]. In the present communication we report on the synthesis of diterpenoid analogs of cantharidin and the corresponding imides by Diels–Alder reaction of accessible natural diterpenoids, lambertianic acid (**I**) and its methyl ester **II** [9].

We have found that thermal reaction of diene **I** with maleic anhydride gives in a low yield the corresponding *exo* adduct as a mixture of (1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-diastereoisomers **IIIa** and **IIIb** (Scheme 1). Table 1 contains the results obtained by optimization of the reaction conditions. The yield of the adducts was the largest when the reaction was carried out in the presence of a Lewis acid, zinc(II) chloride or zinc(II) trifluoromethanesulfonate.

The structure of the adducts follows from the spectral data. Compounds **IIIa**, **IIIb** and **IVa**, **IVb** were assigned the structures of, respectively, (1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-diastereoisomers having *exo* configuration of the anhydride fragment. In the ^{1}H NMR spectra, protons in the bridgehead positions (2-H and 6-H) give rise to doublets at δ 3.08 and 3.18 ppm ($J_{2,6}$ = 8.5 Hz), and they show no coupling with the 1-H and 7-H protons located at the bridgehead positions of the oxygen bridge. The stereoisomer ratios **IIIa**/**IIIb** and **IVa**/**IVb** were determined from the ^{1}H NMR spectra on the basis of the 9-H [δ 6.01 and 6.04 ppm (**IV**)] and 17′-H** [δ 4.35, 4.44 and 4.81, 4.83 ppm (**IV**)] signal intensities. The ^{13}C NMR

* For communication VII, see [1].

** Hereinafter, protons of the terpenoid fragment are denoted with a prime (the labdane numbering is retained).

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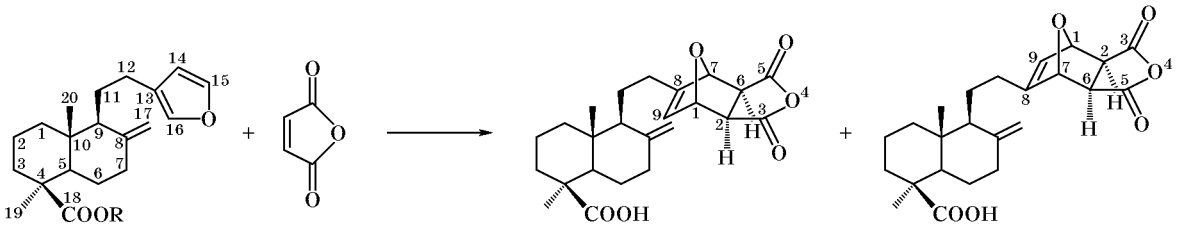
Scheme 1.



I, II **IIIa, IVa** **IIIb, IVb**

I, **III**, R = H; **II**, **IV**, R = Me.

spectrum of isomeric *exo*-adduct mixture **IIIa**/**IIIb** contains a double set of signals from all carbon atoms of the oxatricyclic fragment. For example, signals at δ_C 82.82, 82.90 and 84.00, 84.45 ppm belong to the C^1 and C^7 carbon nuclei.

An additional proof for formation of the *exo* adducts was derived from the NMR spectra of the product obtained by opening of the anhydride ring by heating in boiling methanol in the presence of *p*-toluenesulfonic acid. The reaction is accompanied by migration of the double bond in the diterpenoid fragment, leading to isomeric compounds **Va** and **Vb** (Scheme 2). The structure of the latter follows from the NMR spectra. The ^{1}H NMR spectrum of **Va**/**Vb** contains four double singlets of equal intensities, which belong to methyl group protons, δ, ppm: 0.82 and 0.83 ($C^{20'}H_3$), 1.212 and 1.216 ($C^{19'}H_3$), 1.518 and 1.524 ($C^{17'}H_3$), 3.660 and 3.668 m.d. (OCH_3). The *cis*-arranged 3-H and 4-H protons appear as doublets centered at δ 2.74 and 2.87 ppm (J = 8.0 Hz). They are not coupled with the 2-H and 5-H protons located at the oxygen bridge (according to the two-dimensional H–H correlation spectrum).

Hydrogenation of **IIIa**/**IIIb** over Pd/C in ethyl acetate afforded 91% of diterpenoid cantharidin analog **VIa**/**VIb** (Scheme 2). The ratio of the (1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-diastereoisomers (determined from the 1-H, 7-H, and 17′-H signal intensities) remained almost unchanged (1 : 1).

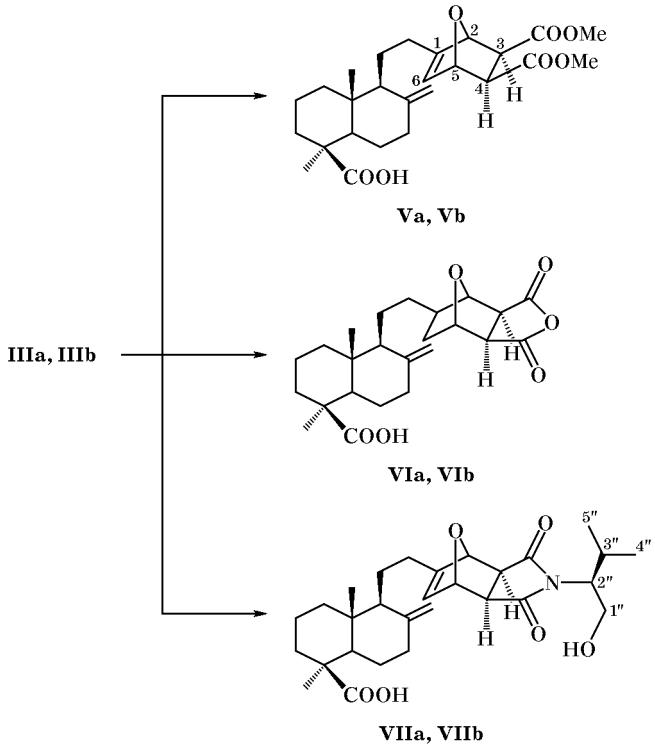
Table 1. Reaction of lambertianic acid (**I**) and its ester **II** with maleic anhydride

Diene no.	Solvent	Time, h	Catalyst	Bath temperature, °C	Yield, %
I	Toluene	20	–	120	27
I	Dioxane	20	–	120	11
I	Dioxane	20	$Eu(fod)_3$	120	49
I	THF	20	Et_2AlCl	–68 to 20	50
I	THF	20	$ZnCl_2$	20	100
I	THF	20	$Zn(OTf)_2$	20	100
II	THF	20	Et_2AlCl	–68 to 20	70

By reaction of **IIIa**/**IIIb** with L-valinol in toluene in the presence of triethylamine we obtained diterpenoid cantharidin imide analog **VIIa**/**VIIb**. The product was a mixture of two diastereoisomers whose ratio (according to the ^{1}H NMR data of the mixture) was the same as the (1*R*,2*S*,6*R*,7*R*)/(1*S*,2*R*,6*S*,7*S*) ratio in the initial adduct.

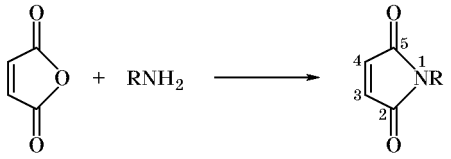
Another route to diterpenoid cantharidin imides may be cycloaddition of dienes **I** and **II** with maleimides. With the goal of studying the effect of the

Scheme 2.



N-substituent in the dienophile on the reaction stereoselectivity and biological activity of new nitrogen-containing heterocycles of the terpene series, apart from *N*-benzylmaleimide (**VIII**), we have synthesized compounds **IX**–**XVIII** with various substituents on the nitrogen (Table 2). Among these, three compounds were prepared for the first time. Maleimides **VIII**–**XVIII** were obtained by heating a mixture of maleic anhydride and the corresponding amine in boiling acetic acid following the procedure described in [10] (Scheme 3). The yield of **VIII**–**XVIII** was 18–43%. Product **XVII** was synthesized in a greater yield (61%) according to the procedure reported in [11] (with the use of oxalyl chloride at the stage of amido acid cyclization).

Scheme 3.



VIII–**XVIII**

VIII, R = CH_2Ph; **IX**, R = $CH_2C_6H_2(OMe)_3$-3,4,5; **X**, R = $CH_2CH_2CH_2COOH$; **XI**, R = CH_2COOH; **XII**, R = CH_2CH_2-C_6H_4OH-4; **XIII**, R = $CH_2CH_2C_6H_4OMe$-2; **XIV**, R = $CHPh_2$; **XV**, R = Ph; **XVI**, $CH(COOH)CH_2Ph$; **XVII**, R = $(CH_2)_2C_6H_2(Bu\text{-}t)_2$-3,5-OH-4; **XVIII**, R = $(CH_2)_3C_6H_2$-$(Bu\text{-}t)_2$-3,5-OH-4.

Lambertianic acid readily reacted with maleimides in THF in the presence of $ZnCl_2$ (20°C, 20 h) to give mixtures of *exo*- and *endo*-adducts, each being a mixture of diastereoisomers (Scheme 4, Table 2). For example, the reaction of diene **I** with *N*-benzylmaleimide gave a mixture of (1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-*exo* (**XIXa**, **XIXb**) and (1*S*,2*S*,6*R*,7*S*)-, (1*R*,2*R*,6*S*,7*R*)-*endo* isomers (**XXa**, **XXb**). It should be noted that the addition of lambertianic acid (**I**) to *N*-*p*-carboxyphenylmaleimide was reported previously [12], but only the formula and the melting point of the adduct were given.

The data in Table 2 show that the ratio of the *endo* and *exo* adducts depends on the N-substituent in the dienophile, other conditions being equal. The isomer ratio in the *N*-arylmethyl derivatives is close to equimolar. The presence of an acidic functional group in the α-position with respect to the nitrogen atom gives rise to increased fraction of the corresponding *exo* adduct (compounds **XXXV**), whereas carboxymethyl group on the nitrogen is likely to fix such reactant orientation in the transition state which corresponds to *exo* addition (the isomer ratio was

Table 2. Reaction of lambertianic acid (**I**) with maleimides **VIII**–**XVIII** in THF in the presence of $ZnCl_2$ (20°C, 20 h)

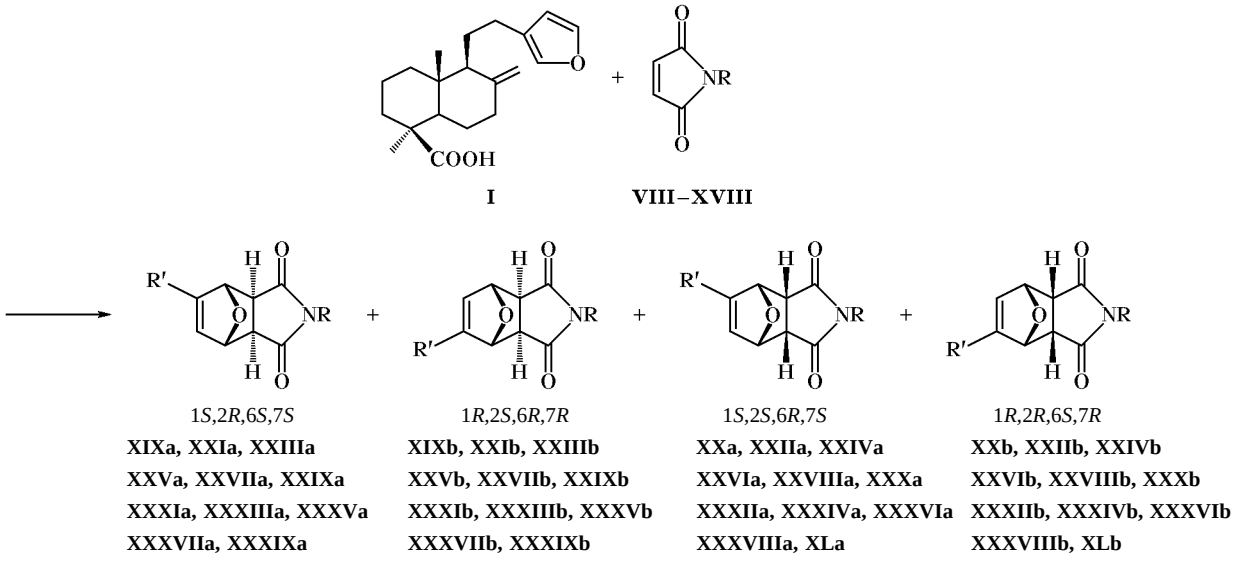
Maleimide	*exo*/*endo* Adducts	Overall yield, %	Ratio *exo*/*endo*
VIII	**XIX/XX**	100	1.0 : 1.5
IX	**XXI/XXII**	78	1.0 : 1.2
X	**XXIII/XXIV**	76	1.0 : 1.5
XI	**XXV/XXVI**	96	1.0 : 2.2
XII	**XXVII/XXVIII**	91	1.0 : 1.2
XIII	**XXIX/XXX**	72	1.0 : 1.3
XIV	**XXXI/XXXII**	67	1.0 : 1.0
XV	**XXXIII/XXXIV**	71	1.0 : 1.3
XVI	**XXXV/XXXVI**	74	2.4 : 1.0
XVII	**XXXVII/XXXVIII**	80	1.0 : 1.0
XVIII	**XXXIX/XL**	75	1.0 : 1.1

determined from the ^1H NMR spectrum of the mixture on the basis of the 9-H and 17′-H signal intensities). The reaction of lambertianic acid methyl ester (**II**) with *N*-benzylmaleimide (**VIII**) under analogous conditions gave a mixture of *endo* and *exo* isomers at a ratio of 2 : 1. The overall yield of the products was 53%. Twofold increase in the reaction time only slightly affects the overall yield, but the fraction of the *exo* isomers increases (*endo* : *exo* = 1.25 : 1). No addition products were obtained by heating of compounds **II** and **VIII** in boiling dioxane for 20 h. Presumably, the adducts undergo fast decomposition into the initial compounds. The mass spectrum contains the molecular ion peaks of the initial diterpenoid, *m*/*z* 330 (35.31%), and maleimide, *m*/*z* 187 (79.85%).

The formation of mixtures of four diastereoisomeric adducts, (1*R*,2*S*,6*R*,7*R*)-*exo*, (1*S*,2*R*,6*S*,7*S*)-*exo*, (1*S*,2*S*,6*R*,7*S*)-*endo*, *and* (*1R*,2*R*,6*S*,7*R*)-*endo* is confirmed by the NMR data. For example, the ^{13}C NMR spectrum of a mixture of cycloadducts **XXIIIa**, **XXIIIb**, **XXIVa**, and **XXIVb** contains two sets of signals from all carbon atoms of the heterocyclic fragment. The signals at δ_C 81.61, 81.66, 82.78, and 82.25 ppm belong to C^1 and C^7 of the *exo* isomer, and those at δ_C 80.07, 80.11, 81.27, and 81.12 ppm, to the corresponding carbon atoms of the *endo* isomer (Table 3).

The product mixtures were difficult to separate, and various techniques were tried in order to isolate individual stereoisomers. By methylation of mixtures of adducts **XIX**/**XX**, **XXI**/**XXII**, and **XXXV**/**XXXVI** and subsequent separation by column chromatography we succeeded in isolating methyl esters of *exo*

Scheme 4.



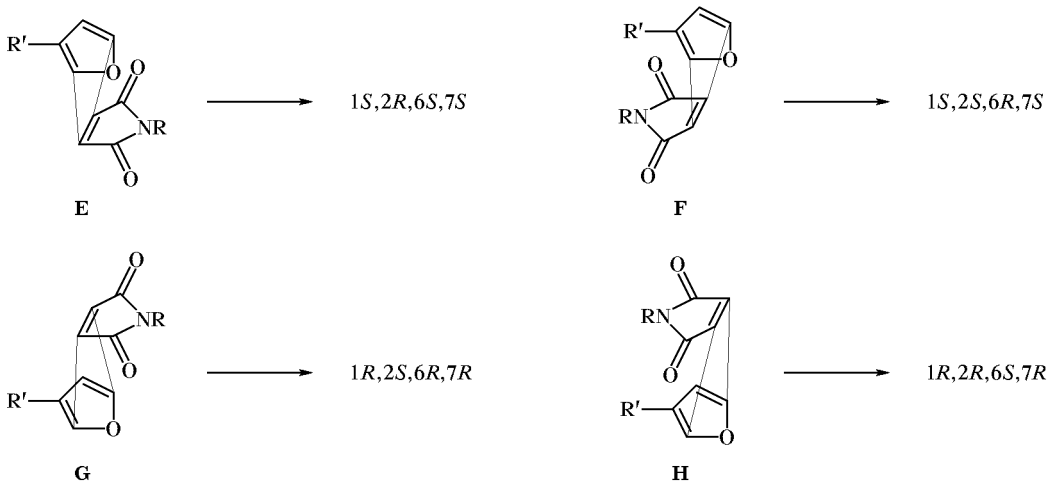
I **VIII–XVIII**

1*S*,2*R*,6*S*,7*S*	1*R*,2*S*,6*R*,7*R*	1*S*,2*S*,6*R*,7*S*	1*R*,2*R*,6*S*,7*R*
XIXa, XXIa, XXIIIa	**XIXb, XXIb, XXIIIb**	**XXa, XXIIa, XXIVa**	**XXb, XXIIb, XXIVb**
XXVa, XXVIIa, XXIXa	**XXVb, XXVIIb, XXIXb**	**XXVIa, XXVIIIa, XXXa**	**XXVIb, XXVIIIb, XXXb**
XXXIa, XXXIIIa, XXXVa	**XXXIb, XXXIIIb, XXXVb**	**XXXIIa, XXXIVa, XXXVIa**	**XXXIIb, XXXIVb, XXXVIb**
XXXVIIa, XXXIXa	**XXXVIIb, XXXIXb**	**XXXVIIIa, XLa**	**XXXVIIIb, XLb**

XIX, **XX**, R = CH_2Ph; **XXI**, **XXII**, R = $CH_2C_6H_2(OMe)_3$-3,4,5; **XXIII**, **XXIV**, R = $(CH_2)_3COOH$; **XXV**, **XXVI**, R = CH_2COOH; **XXVII**, **XXVIII**, R = $CH_2CH_2C_6H_4OH$-4; **XXIX**, **XXX**, R = $CH_2CH_2C_6H_4OMe$-2; **XXXI**, **XXXII**, R = $CHPh_2$; **XXXIII**, **XXXIV**, R = Ph; **XXXV**, **XXXVI**, R = $CH(COOH)CH_2Ph$; **XXXVII**, **XXXVIII**, R = $(CH_2)_2C_6H_2(Bu\text{-}t)_3$-3,5-OH-4; **XXXIX**, **XL**, R = $(CH_2)_3C_6H_2(Bu\text{-}t)_3$-3,5-OH-4; R′ = 13,14,15,16-tetranor-18-carboxylabd-8(17)-en-12-yl.

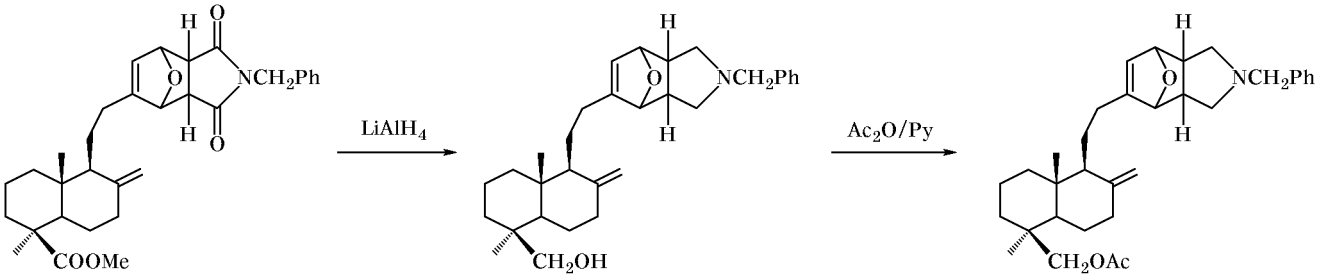
(**XIXa**/**XIXb**) and *endo* isomers (**XXa**/**XXb**) as amorphous powders having sharp melting points. Likewise, *exo* isomers **XXXVIIa**/**XXXVIIb** and **XXXIXa**/**XXXIXb** were separated from the corresponding *endo*-isomers **XXXVIIIa**/**XXXVIIIb** and **XLa**/**XLb** by column chromatography. It was more difficult to isolate pure diastereoisomers. Individual (1*S*,2*S*,6*R*,7*S*)-diastereoisomer **XLa** was isolated from the reaction mixture obtained from maleimide **XVIII** containing a sterically shielded phenolic fragment (Table 2). The ^1H signals of stereoisomeric pairs of methyl esters derived from *exo* isomers **XIXa**/**XIXb** and *endo* isomers **XXa**/**XXb** were assigned. Protons at the bridgehead carbon atoms (2-H and 6-H) in *exo* adducts **XIXa** and **XIXb** appear in the ^1H NMR spectrum as doublets at δ 2.77 and 2.87 ppm ($J_{2,6}$ = 6.5 Hz) and δ 2.785 and 2.87 ppm ($J_{2,6}$ 6.5 Hz), respectively. No coupling was observed between the above protons and those located at the oxygen bridge (1-H and 7-H). This is also confirmed by the data of H,H-COSY experiment. Isomers **XXa** and **XXb** were thus assigned the *endo* structure. The 2-H and 6-H

Scheme 5.



E **F** **G** **H**

Scheme 6.



XLIa, XLIb, XLIIa, XLIIb **XLIIIa, XLIIIb, XLIVa, XLIVb** **XLVa, XLVb, XLVIa, XLVIb**

protons therein give signals in the region δ 3.44–3.50 ppm, and they display couplings with protons in the other bridgehead positions ($J_{2,6}$ = 7.6, $J_{6,7}$ = 5.0, 5.1 Hz) (δ 4.95 and 5.18 ppm). In the spectra of **XIXa**/**XIXb**, protons of the methylene group at the nitrogen give rise to a singlet at 4.61 ppm. The corresponding protons in *endo* isomers **XXa** and **XXb** are magnetically nonequivalent, and they appear as doublets at δ 4.48 and 4.36 ppm (^2J = 13.9 Hz) (one diastereoisomer) and at δ 4.46 and 4.35 ppm (^2J = 13.8 Hz) (the other diastereoisomer). Pure isomer **XLa** was assigned the (1*S*,2*S*,6*R*,7*S*)-*endo* configuration on the basis of the following considerations. The 2-H and 6-H signals are doublets of doublets at δ 3.46 and 3.45 ppm, $J_{2,6}$ = 5.9, $J_{6,7}$ = 2.8, $J_{1,2}$ = 2.9 Hz. The olefinic proton signal is located at δ 5.88 ppm. It is split into a quartet due to coupling with 7-H and two 12′-H protons of the terpene moiety. The 7-H and 1-H resonances are observed, respectively, at δ 5.22 (d.q, *J* = 1.7, 2.9 Hz) and 5.06 ppm (d.d, *J* = 1.7, 2.8 Hz). NOESY experiment showed NOE effect for 7-H and methylene protons at the exocyclic double bond. Signals of the latter in the spectrum of the (1*S*,2*S*,6*R*,7*S*)-*endo* diastereoisomer are located in a weaker field relative to the corresponding signals of the (1*R*,2*R*,6*S*,7*R*) isomer.

Thus the cyloaddition of lambertianic acid to N-substituted maleimides leads to formation of four diastereoisomeric products. It should be noted that Zhao *et al.* [13] reported on the reaction of maleic anhydride with a furan diterpenoid, chedichenone, which also gave oxygen-bridged adducts as a mixture of two *endo* and two *exo* isomers.

Scheme 5 shows model structures **E**–**H** which simulate possible transition states in the cycloaddition of lambertianic acid to N-substituted maleimides. Taking into account that rotation of the furan ring in molecule **I** is not restricted, predominant formation of a particular isomer could be determined by the overall effect of steric factors.

The adducts obtained were subjected to some transformation. By reduction of mixtures of methyl esters **XLIa**/**XLIb** and **XLIIa**/**XLIIb** derived from adducts **XIXa**/**XIXb** and **XXa**/**XXb** we obtained N-substituted tricyclanes having a pyrrole fragment. The reduction was carried by heating the substrates for a short time in THF in the presence of excess lithium aluminum hydride; as a result, *N*-benzyl derivatives **XLIIIa**/**XLIIIb** and **XLIVa**/**XLIVb** (Scheme 6) were formed. The transformation of the carbonyl groups in compounds **XLIa**/**XLIb** and **XLIIa**/**XLIIb** is confirmed by the synthesis of acetates **XLVa**/**XLVb** and **XLVIa**/**XLVIb** by treatment of **XLIIIa**/**XLIIIb** and **XLIVa**/**XLIVb** with acetic anhydride and pyridine.

Thus the Diels–Alder reaction of lambertianic acid with cyclic dienophiles provides a convenient route to terpenoid cantharidin analogs. The dienophile nature determines the stereochemistry of the addition. The reaction of lambertianic acid with maleic anhydride yields exclusively the corresponding *exo* adducts, while with N-substituted maleimides both *endo* and *exo* adducts are formed, whose ratio depends on the substituent on the nitrogen. In each case, diastereoisomeric pairs were obtained. By analysis of the ^{1}H and ^{13}C NMR spectra of particular isomers we succeeded in assigning them to the (1*S*,2*R*,6*S*,7*S*)-, 1*R*,2*S*,6*R*,7*R*)-*exo* and (1*S*,2*S*,6*R*,7*S*)-, 1*R*,2*R*,6*S*,7*R*)-*endo* series. The products obtained can be used in the synthesis of diterpenoid analogs of the isoindole and benzophthalimide series.

EXPERIMENTAL

The IR spectra were recorded on a VECTOR-22 spectrometer from samples pelleted with KBr. The UV spectra were measured on an HP 8453 UV-Vis spectrophotometer from solutions in ethanol (c = 10^{-4} M). The NMR spectra were obtained on Bruker AC-200 (200.13 MHz for ^{1}H and 50.32 MHz for ^{13}C) and Bruker DRX-500 instruments (500.13 MHz for

Table 3. ^{13}C NMR spectra of new tricyclo[5.2.1.$0^{2,6}$]decenes[a]

Atom	III	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII
C^1	84.00 d, 84.45 d	82.78 d, 83.25 d	81.61 d, 81.66 d	82.68 d, 83.17 d	81.01 d, 81.98 d	82.63 d, 83.12 d	80.49 d, 81.54 d
C^2	48.08 d, 48.17 d	46.92 d, 47.03 d	46.01 d	46.45 d	46.44 d	46.83 d, 46.92 d	45.89 d, 45.98 d
C^3	169.99 s,[a] 170.01 s[a]	176.43 s,[b] 176.45 s[b]	174.45 s,[c] 171.19 s[c]	175.43 s,[d] 175.50 s[d]	173.36 s,[e] 173.42 s[e]	176.33 s,[f] 176.45 s[f]	174.67 s,[g] 175.34 s[g]
C^5	170.31 s,[a] 170.34 s[a]	176.56 s,[b] 176.57 s[b]	175.21 s[c]	175.55 s[d]	174.19 s[e]	176.50 s[f]	175.36 s[g]
C^6	50.17 d, 50.22 d	49.09 d, 49.13 d	47.26 d, 47.29 d	47.27 d, 47.30 d	47.16 d, 47.26 d	49.02 d, 49.07 d	47.22 d, 47.32 d
C^7	82.82 d, 82.90 d	81.61 d, 81.66 d	80.07 d, 80.11 d	81.49 d, 81.53 d	80.09 d, 80.15 d	81.44 d, 81.48 d	80.00 d, 80.05 d
C^8	152.63 s, 152.98 s	152.22 s, 152.63 s	151.02 s, 151.52 s	152.21 s, 152.62 s	150.77 s, 151.28 s	152.20 s, 152.62 s	150.90 s, 151.35 s
C^9	127.87 d, 128.51 d	127.58 d, 128.30 d	124.59 d, 125.56 d	127.55 d, 128.27 d	124.76 d, 125.82 d	127.50 d, 128.21 d	124.77 d, 125.52 d
$C^{1'}$	38.93 t	39.05 t, 39.10 t[b]	38.91 t, 39.00 t[c]	38.84 t	38.73 t	38.96 t, 39.00 t	39.03 t
$C^{2'}$	19.51 t	19.71 t	19.71 t	19.70 t	19.70 t	19.65 t	19.70 t
$C^{3'}$	37.56 t	37.66 t, 37.70 t	37.45 t, 37.51 t	37.60 t	37.48 t	37.63 t, 37.66 t	37.61 t
$C^{4'}$	40.31 s	40.40 s,[h] 40.45 s	40.25 s, 40.35 s[j]	40.26 s,[i] 40.35 s	40.16 s, 40.25 s[k]	40.37 s	39.81 s, 40.22 s
$C^{5'}$	55.91 d, 55.92 d	56.05 d, 56.08 d	55.77 d, 56.00 d	55.93 d, 55.97 d	55.91 d, 55.93 d	55.99 d, 55.96 d	55.91 d, 56.00 d
$C^{6'}$	25.82 t	25.88 t	25.84 t	26.11 t	26.10 t	25.81 t	25.79 t
$C^{7'}$	38.45 t	38.48 t	38.43 t	38.34 t, 38.35 t	38.22 t, 38.34 t	38.40 t	38.39 t
$C^{8'}$	147.19 s, 147.49 s	147.43 s, 147.56 s	147.16 s, 147.26 s	147.37 s, 147.44 s	147.13 s	147.21 s, 147.52 s	147.19 s, 147.25 s
$C^{9'}$	55.01 d, 55.60 d	55.10 d, 55.23 d	55.08 d, 55.23 d	54.98 d, 55.63 d	54.97 d, 55.26 d	55.01 d, 55.66 d	55.08 d, 55.74 d
$C^{10'}$	43.30 s, 43.91 s	44.06 s, 44.10 s	44.05 s, 44.06 s	44.04 s,[i] 44.06 s	44.01 s, 44.03 s[k]	43.96 s	43.94 s,[l] 43.99 s[l]
$C^{11'}$	25.76 t	25.91 t, 26.20 t	26.00 t, 26.40 t	27.10 t	27.00 t	26.08 t	26.00 t
$C^{12'}$	23.30 t	21.18 t	20.77 t	21.00 t	21.40 t	21.00 t, 21.32 t	20.72 t, 21.20 t
$C^{17'}$	106.17 t, 106.32 t	106.48 t, 106.53 t	106.39 t, 106.50 t	106.35 t, 106.51 t	106.31 t, 106.42 t	106.30 t, 106.46 t	106.36 t, 106.43 t
$C^{18'}$	183.20 s	183.74 s,[h]	183.67 s,[j]	184.13 s, 184.22 s	183.98 s	183.36 s	183.32 s, 183.48 s[g]
$C^{19'}$	28.68 q	28.85 q, 28.95 q	28.83 q, 28.89 q	28.88 q	28.86 q	28.75 q, 28.78 q	28.75 q, 28.81 q
$C^{20'}$	12.46 q, 12.50 q	12.80 q	12.80 q	12.80 q	12.80 q	12.53 q, 12.58 q	12.48 q, 12.62 q

Table 3. (Contd.)

Atom	III	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII
$C^{1''}$	–	22.60 t, 22.73 t	22.44 t	40.26 t	39.26 t	129.38 s	129.08 s,[l]
$C^{2''}$	–	37.73 t,[h] 37.74 t[h]	37.74 t[j]	169.60 s	169.60 s	129.85 d	129.44 d,[g]
$C^{3''}$	–	178.26 s[h]	178.12 s[j]	–	–	115.16 d[f]	115.30 d[g]
$C^{4''}$	–	–	–	–	–	154.44 s,	154.58 s, 154.64 s
$C^{5''}$	–	–	–	–	–	115.26 d	115.32 d[g]
$C^{6''}$	–	–	–	–	–	129.85 d	129.69 d
NCH_2	–	–	–	–	–	32.58 t	32.78 t
CH_2Ar	–	–	–	–	–	40.27 t	40.38 t, 40.41 t

Atom	XXIX	XXX	XXXI	XXXII	XXXIII	XXXVII	XXXVIII
C^1	82.50 d, 83.00 d	81.28 d, 81.68 d	83.13 d, 83.58 d	81.63 d, 81.20 d	80.99 d, 81.71 d	82.64 d, 83.16 d	81.30 d, 81.71 d
C^2	47.20 d	45.79 d, 45.86 d	46.85 d, 46.95 d	45.76 d	45.95 d, 45.98 d	46.87 d, 46.97 d	45.83 d, 45.92 d
C^3	176.10 s[m]	174.27 s,[n] 174.32 s[n]	175.82 s,[o] 175.97 s[o]	174.47 s,[p]	174.49 s,[q]	176.10 s,[r] 170.12 s[r]	174.33 s
C^5	176.25 s[m]	175.03 s[n]	176.00 s[o]	174.56 s[p]	175.19 s	170.24 s,[r] 170.29 s[r]	174.99 s
C^6	49.00 d	47.15 d, 47.24 d	49.02 d, 49.07 d	47.94 d	47.24 d, 47.28 d	49.09 d, 49.13 d	47.20 d, 47.32 d
C^7	81.44 d, 81.47 d	79.92 d, 80.01 d	81.92 d, 81.96 d	80.38 d, 80.41 d	79.99 d, 81.71 d	81.46 d, 81.51 d	79.96 d, 80.12 d
C^8	152.10 s, 152.60 s	150.76 s, 151.10 s	152.27 s, 152.69 s	150.05 s, 151.36 s	151.22 s, 151.87 s	152.14 d, 152.62 d	150.82 d, 151.15 d
C^9	127.50 d, 128.20 d	124.86 d, 125.46 d	127.60 d,[o] 127.87 d[o]	124.92 d	124.89 d, 125.67 d	127.53 s, 128.33 s	125.15 s, 125.43 s
$C^{1'}$	38.89 t	38.89 t	39.06 t, 39.09 t	38.95 t	39.00 t	39.00 t, 39.04 t	39.02 t
$C^{2'}$	19.67 t	19.50 t	19.70 t	19.69 t	19.72 t	19.67 t	19.47 t
$C^{3'}$	37.67 t	37.58 t	37.72 t, 37.75 t	37.70 t	37.75 t	37.64 t, 37.68 t	37.60 t
$C^{4'}$	40.33 s	40.16 s	40.33 s, 40.43 s	40.30 s, 40.33 s	40.26 s, 40.38 s	40.30 s, 40.38 s	40.18 s
$C^{5'}$	55.98 d	55.98 d	56.04 d, 56.05 d	55.97 d	56.00 d, 56.03 d	56.00 d, 56.02 d	55.93 d
$C^{6'}$	25.78 t	25.75 t	25.88 t, 25.90 t	25.83 t	25.80 t, 25.83 t	25.83 t	25.75 t
$C^{7'}$	38.39 t	38.37 t	38.46 t, 38.49 t	38.41 t	38.39 t, 38.43 t	38.43 t, 38.44 t	38.37 t
$C^{8'}$	147.16 s, 147.38 s	147.17 s, 147.36 s	147.26 s, 147.58 s	147.00 s, 147.19 s	147.12 s, 147.34 s	147.22 s, 147.57 s	147.13 s, 147.15 s

Table 3. (Contd.)

Atom	XXIX	XXX	XXXI	XXXII	XXXIII	XXXVII	XXXVIII
$C^{9'}$	55.20 d, 55.91 d	55.14 d, 55.47 d	55.13 d, 55.75 d	55.20 d	54.99 d, 55.52 d	54.93 d, 55.69 d	55.23 d, 55.25 d
$C^{10'}$	49.96 s	43.90 s	44.01 s	44.00 s	43.99 s, 44.01 s	43.98 s, 43.99 s	43.89 s, 43.60 s
$C^{11'}$	25.75 t, 25.79 t	27.17 t, 27.22 t	26.20 t	26.66 t	27.26 t	25.74 t, 26.09 t	27.30 t
$C^{12'}$	20.65 t, 21.60 t	20.65 t, 21.60 t	21.11 t, 21.60 t	21.22 t	21.20 t, 21.36 t	20.95 t, 21.37 t	20.62 t
$C^{17'}$	106.36 t	106.39 t	106.34 t, 106.52 t	106.61 t	106.45 t, 106.55 t	106.28 t, 106.46 t	106.42 t
$C^{18'}$	183.53 s	183.53 s	183.07 s	183.67 s	183.24 s	183.61 s	183.48 s
$C^{19'}$	28.81 q	28.76 q	28.84 q, 28.86 q	28.85 q	28.85 q	28.79 q, 28.82 q	28.75 q, 28.81 q
$C^{20'}$	12.57 q	12.51 q	12.63 q, 12.67 q	12.57 q	12.58 q	12.58 q, 12.62 q	12.57 q
$C^{1''}$	125.91 s	125.74 s, 125.89 s	137.29 s, 135.31 s	137.09 s, 137.26 s	131.02 s, 131.10 s	135.77 s	135.91 s
$C^{2''}$	130.45 d	130.07 d, 130.20 d	127.65 d,^{o} 127.72 d,^{o} 127.76 d,^{o} 128.23 d^{o}	127.55 d,^{p} 127.62 d,^{p} 127.67 d,^{p} 127.70 d^{p}	124.55 d^{q}	125.16 d	124.86 d, 125.03 d
$C^{3''}$	127.84 d	127.97 d, 127.93 d	128.30 d,^{o} 128.32 d,^{o} 128.35 d^{o}	128.10 d,^{p} 128.13 d,^{p} 128.19 d^{p}	124.64 d	128.26 s	127.87 s, 127.98 s
$C^{4''}$	130.07 d	130.20 d	128.36 d,^{o} 128.38 d,^{o} 128.40 d^{o}	128.23 d,^{p} 128.27 d,^{p} 128.28 d^{p}	124.66 d^{q}	152.25 s	152.32 s, 152.33 s
$C^{5''}$	110.04 d, 110.09 d	110.09 d, 110.12 d	128.42 d,^{o} 128.44 d,^{o} 128.47 d^{o}	128.38 d,^{p} 128.44 d,^{p} 128.46 d^{p}	124.64 d^{q}	128.26 s	127.87 s, 127.98 s
$C^{6''}$	157.48 s	157.52 s	128.49 d,^{o} 128.56 d,^{o} 128.57 d,^{o} 128.66 d^{o}	128.48 d,^{p} 128.65 d,^{p}, 128.83 d^{p}	124.55 d^{q}	125.16 d	124.86 d, 125.03 d
NCH_2	28.63 t	28.40 t	–	–	–	33.37 t	33.40 t, 33.78 t
CH_2Ar	38.00 t	37.88 t	–	–	–	40.27 t	40.12 t
CH	–	–	44.01 t	44.00 t	–	–	–
OMe_{arom}	55.11 q	55.14 q	–				
$C(\mathbf{C}H_3)_3$					–	30.14 q	30.14 q
$\mathbf{C}(CH_3)_3$				–	–	34.10 s	34.10 s

Atom	XXXIX	XLa	XLI	XLII	XLVII	XLVIII	XLIX
C^{1}	82.70 d, 83.21 d	80.93 d	82.77 d, 83.23 d	80.80 d, 81.67, d	82.89 d, 82.34 d	80.56 d, 81.56 d	83.05 d, 83.10 d

Table 3. (Contd.)

Atom	**XXXIX**	**XLa**	**XLI**	**XLII**	**XLVII**	**XLVIII**	**XLIX**
C^2	46.86 d, 46.96 d	45.91 d	46.98 d, 47.09 d	45.74 d, 45.80 d	47.01 d, 47.12 d	45.71 d, 45.81 d	46.65 d, 46.74 d
C^3	176.34 s, 176.36 s	174.47 s[s]	175.83 s,[t] 175.84 s	173.93 s,[u] 173.94 s[u]	175.94 s[v]	173.98 s,[w] 174.03 s	175.50 s[x]
C^5	176.11 s 176.52 s	174.83 s,	175.60 s[t] 176.01 s[t]	176.49 s,	175.16 s	175.99 s,[w] 174.84 s	174.77 s[x]
C^6	49.03 d, 49.09 d	47.22 d	49.17 d, 49.22 d	47.32 d, 47.35 d	49.22 d, 49.25 d	47.35 d, 47.37 d	48.85 d, 48.90 d
C^7	81.51 d, 81.57 d	80.00 d	81.54 d, 81.58 d	80.12 d, 80.16 d	81.65 d, 81.70 d	80.04 d, 80.11 d	81.36 d, 81.38 d
C^8	152.16 d, 152.64 d	150.66 d	152.20 s, 152.61 s	150.46 s, 151.03 s	152.31 s, 152.67 s	150.43 s, 150.93 s	152.00 s, 152.10 s
C^9	127.51 s, 128.30 s	125.77 s	127.53 d, 128.22 d	124.70 d, 126.19 d	127.54 d, 128.21 d	124.92 d, 126.08 d	126.66 d, 126.68 d
$C^{1'}$	39.01 t, 39.07 t	38.91 t	39.05 t, 39.08 t	38.95 t, 38.98 t	39.09 t, 39.12 t	38.87 t, 38.99 t	39.06 t
$C^{2'}$	19.40 t, 19.80 t	19.66 t	19.72 t, 19.73 t	19.75 t	19.75 t	19.77 t	19.73 t
$C^{3'}$	37.68 t, 37.72 t	37.61 t	37.94 t, 37.98 t	37.96 t, 38.02 t	37.92 t, 38.00 t	37.99 t, 38.02 t	37.98 t
$C^{4'}$	40.30 s, 40.41 s	40.21 s	40.08 s, 40.18 s	39.96 s, 40.12 s	40.12 s, 40.22 s	40.01 s, 40.13 s	40.17 s
$C^{5'}$	56.02 d, 56.04 d	55.95 d	56.02 d, 56.04 d	55.99 d, 56.02 d	56.06 d	55.96 d	56.00 d, 56.02 d
$C^{6'}$	25.78 t	25.77 t	26.02 t, 26.11 t	26.49 t, 26.57 t	25.99 t, 26.00 t	26.03 t, 26.05 t	25.84 t
$C^{7'}$	38.46 t	38.38 t	38.45 t, 38.47 t	38.44 t, 38.46 t	38.44 t, 38.47 t	38.42 t, 38.49 t	38.44 t, 38.46 t
$C^{8'}$	147.26 s, 147.59 s	147.06 s	147.33 s, 147.65 s	147.06 s, 147.42 s	147.45 s, 147.69 s	147.11 s, 147.35 s	147.34 s, 147.90 s
$C^{9'}$	54.98 d, 55.73 d	54.94 d	55.04 d, 55.69 d	54.81 d, 55.17 d	55.07 d, 55.72 d	54.94 d, 55.28 d	55.66 d, 55.99 d
$C^{10'}$	43.80 s, 44.00 s	43.95 s	44.08 s, 44.09 s	44.10 s, 44.11 s	44.09 s, 44.10 s	44.11 s, 44.12 s	44.08 s, 44.09 s
$C^{11'}$	25.86 t, 26.10 t	27.13 t	25.82 t, 26.02 t	26.02 t	25.88 t, 26.17 t	26.78 t, 26.79 t	26.02 t
$C^{12'}$	21.00 t, 21.30 t	20.96 t	21.00 t, 21.36 t	21.02 t	21.01 t, 21.33 t	21.19 t, 21.40 t	21.01 t, 21.04 t
$C^{17'}$	106.30 t, 106.48 t	106.49 t	106.16 t, 106.34 t	106.31 t, 106.41 t	106.18 t, 106.35 t	106.20 t, 106.35 t	106.16 t, 106.32 t
$C^{18'}$	183.41 s	183.57 s	177.42 s	177.50 s, 177.52 s	177.48 s	177.51 s	177.48 s
$C^{19'}$	28.85 q, 29.12 q	28.79 q	28.59 q, 28.62 q	28.62 q, 28.65 q	28.62 q	28.65 q	28.61 q, 28.64 q
$C^{20'}$	12.80 q	12.61 q	12.37 q, 12.42 q	12.32 q, 12.43 q	12.40 q, 12.44 q	12.29 q, 12.43 q	12.37 q

Table 3. (Contd.)

Atom	**XXXIX**	**XLa**	**XLI**	**XLII**	**XLVII**	**XLVIII**	**XLIX**
$C^{1''}$	135.60 s	135.64 s	135.32 s, 135.33 s	135.37 s, 135.43 s	130.76 s, 130.94 s	130.94 s, 130.99 s	53.66 d, 53.67 d
$C^{2''}$	124.55 d,[y] 124.62 d[y]	124.46 d[s]	127.88 d[t]	128.35 d,[u] 128.37 d[u]	104.40 d	106.36 d[w]	33.80 t
$C^{3''}$	131.46 s	130.96 s	128.40 d[t]	128.96 d[u]	152.90 s[v]	152.94 s[w]	136.20 s, 136.21 s
$C^{4''}$	151.76 s	151.81 s	127.54 d	127.78 d, 127.92 d	130.76 s, 130.94 s	130.94 s, 130.98 s	128.08 d[x]
$C^{5''}$	131.40 s	130.96 s	128.41 d[t]	129.00 d	152.94 s[v]	153.14 s[w]	128.90 d[x]
$C^{6''}$	124.71 d	124.48 d[s]	127.91 d[t]	128.38 d, 128.39 d	104.40 d	106.41 d[w]	128.23 d, 128.31 d
$C^{7''}$	–	–	–	–	–	–	128.92 d
$C^{8''}$	–	–	–	–	–	–	128.22 d
CH	–	–	42.21 t, 42.22 t	41.97 t, 42.00 t	42.26 t	42.27 t	–
NCH_2	34.13 t	34.10 t	–	–	–	–	–
$CH_2\mathbf{C}H_2CH_2$	32.76 t, 32.82 t	28.60 t	–	–	–	–	–
CH_2Ar	38.77 t	38.23 t	–	–	–	–	–
OMe	–	–	–	50.98 q	–	–	51.02 q, 52.66 q
OMe_{arom}	–	–	–	–	55.90 q, 55.92 q	55.94 q, 55.97 q	–
COOMe	–	–					168.49 s
$C(\mathbf{C}H_3)_3$	30.18 q	28.60 q	–	–	–	–	–
$\mathbf{C}(CH_3)_3$	34.13 s	34.10 s, 34.12 s					

[a] In all cases, except for compound **XLa**, the data for stereoisomer mixtures **a**/**b** are given.
[b–y] Alternative assignment is possible.

^1H and 125.76 MHz for ^{13}C) from solutions in $CDCl_3$. The signals in the NMR spectra were assigned using various proton–proton and carbon–proton correlation techniques (COSY, COLOC, CORRD), two-dimensional ^1H NMR spectroscopy, NOE experiments (NOESY), and also the data of [1]. The mass spectra (70 eV) were run on a Finnigan MAT-8200 high-resolution mass spectrometer. The melting points were determined on a Koffler device.

The progress of reactions was monitored by TLC on Silufol UV-254 plates. The products were isolated by column chromatography on KSK silica gel (0–70 μm) or aluminum oxide (compounds **XLI** and **XLIV**) using chloroform–methanol (200 : 1, 50 : 1) as eluent. The elemental compositions of the prepared compounds were consistent with the calculated ones. The ^{13}C NMR spectra of the adducts are given in Table 3. The product yields given in Tables 1 and 2 were determined from the intensity ratio of signals belonging to the adducts and lambertianic acid in the reaction mixtures.

L-Valinol was prepared by the procedure reported in [14], and zinc(II) trifluoromethanesulfonate was obtained as described in [15]. The spectral parameters and analytical data of maleimides **VIII** [16], **X**, **XI** [17], **XII** [18], **XIII** [19], **XIV** [20], **XV** [21], and **XVI** [22] were in agreement with published data.

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4,10-dioxatricyclo[5.2.1.0^{2,6}]dec-8-ene-3,5-diones (IIIa/IIIb). $C_{24}H_{30}O_6$. *a.* Maleic anhydride, 0.37 g (3.80 mmol), was added to a solution of 1.0 g

(3.17 mmol) of lambertianic acid (**I**) in 20 ml of dioxane. The mixture was heated in a sealed ampule under argon for 20 h. The ampule was opened, and the solvent was distilled off under reduced pressure. The residue contained unchanged initial compound **I** and adducts **IIIa** and **IIIb** (Table 1).

b. Maleic anhydride, 0.37 g (3.80 mmol), and $Eu(fod)_3$, 0.005 equiv, were added to a solution of 1.0 g (3.17 mmol) of lambertianic acid (**I**) in 25 ml of dioxane, and the mixture was heated for 20 h in a sealed ampule under argon. The ampule was opened, and the solvent was distilled off under reduced pressure. The residue contained unchanged initial compound **I** and adducts **IIIa** and **IIIb** (Table 1).

c. Chlorodiethylaluminum, 0.001 g (0.0011 mmol), was added at –68°C to a solution of 1.0 g (3.17 mmol) of lambertianic acid (**I**) in 20 ml of anhydrous THF while stirring under argon. The mixture was stirred for 5 min at –68°C, and 0.37 g (3.80 mmol) of maleic anhydride was added. The mixture was allowed to warm up to 20°C and was kept for 20 h at that temperature with intermittent stirring. When the reaction was complete, the mixture was poured onto ice, neutralized with dilute sulfuric acid, and extracted with methylene chloride (3×30 ml). The combined extracts were dried over Na_2SO_4 and evaporated. The residue contained unchanged initial compound **I** and adducts **IIIa** and **IIIb** (Table 1).

d. Freshly calcined zinc(II) chloride, 0.41 g (3.2 mmol), was added with stirring under a stream of argon to a solution of 1.0 g (3.17 mmol) of lambertianic acid in 20 ml of anhydrous THF. Maleic anhydride, 0.37 g (3.8 mmol), was then added, and the mixture was kept for 20 h at room temperature with intermittent stirring. When the reaction was complete, the mixture was diluted with 30 ml of water, the organic layer was separated, and the aqueous layer was extracted with $CHCl_3$ (2×25 ml). The extracts were combined with the organic phase, washed with water (2×20 ml), and dried over $MgSO_4$. The solvent was removed, the residue was ground with hexane, and the precipitate was filtered off. Yield of **IIIa**/**IIIb** 1.04 g (74%; Table 1).

e. Zinc(II) trifluoromethanesulfonate, 1.15 g (0.32 mmol), and maleic anhydride, 0.37 g (3.8 mmol), were added with stirring at 0°C under argon to a solution of 1.0 g (3.15 mmol) of lambertianic acid (**I**) in 20 ml of anhydrous THF, and the mixture was kept for 20 h at room temperature with intermittent stirring. A saturated solution of NH_4Cl, 10 ml, and methylene chloride, 10 ml, were added, and the mixture was stirred for 2 h. The organic layer was separated, and the aqueous layer was extracted with methylene chloride (2×25 ml). The extracts were combined with the organic phase, dried over Na_2SO_4, and evaporated. The residue was ground with hexane, and the precipitate was filtered off. Yield of **IIIa**/**IIIb** 1.10 g (80%), mp 59–62°C. In all cases, the ratio of (1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-diastereoisomers was 1:1 (Table 1). IR spectrum, ν, cm^{-1}: 845, 1196, 1231, 1634, 1724, 2878, 3432. ^1H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.56 s (6H, $C^{20'}H_3$), 1.01 m (4H, 1′-H, 3′-H), 1.20 s (6H, $C^{19'}H_3$), 1.23 m (4H, 2′-H, 5′-H), 1.53 m (6H, 9′-H, 12-H, 12′-H), 1.62 m (2H, 1′-H), 1.83 m (6H, 2′-H, 6′-H, 7′-H), 2.07 m (4H, 6′-H, 11′-H), 2,14 m (2H, 3′-H), 2.35 m (4H, 11′-H, 7′-H), 3.08 d (2H, 2-H, *J* = 8.5), 3.18 d (2H, 6-H, *J* = 8.5), 4.39 s and 4.42 s (2H, 17′-H), 4.83 s (2H, 17′-H), 5.11 s and 5.13 s (2H, 1-H), 5.33 s (2H, 7-H), 6.03 s (2H, 9-H).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-8-[18-Methoxycarbonyl-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4,10-dioxatricyclo[5.2.1.0^{2,6}]dec-8-ene-3,5-diones (IVa/IVb). $C_{25}H_{32}O_6$. Compounds **IVa**/**IVb** were synthesized as described above for **IIIa**/**IIIb**, method *c*. ^1H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.57 s (6H, $C^{20'}H_3$), 1.01 m (4H, 1′-H, 3′-H), 1.19 s (6H, $C^{19'}H_3$), 1.23 m (4H, 2′-H, 5′-H), 1.56 m (6H, 9′-H, 12-H, 12′-H), 1.80 m (2H, 1′-H), 1.83 m (6H, 2′-H, 6′-H, 7′-H), 1.94 (2H, 6′-H), 2.07 m (2H, 11′-H), 2.11 m (2H, 3′-H), 2.38 m (4H, 11′-H, 7′-H), 3.08 d (2H, 2-H, *J* = 6.5), 3.18 d (2H, 6-H, *J* = 6.5), 3.67 s (6H, OCH_3), 4.35 s and 4.44 s (2H, 17′-H), 4.81 s and 4.83 s (2H, 17′-H), 5.10 s and 5.12 s (2H, 1-H), 5.32 s (2H, 7-H), 6.01 q and 6.04 q (2H, 9-H).

Dimethyl (1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-8-[18-carboxy-13,14,15,16-tetranorlabd-8(9)-en-12-yl]-7-oxabicyclo[2.2.1]hex-1-ene-3,4-dicarboxylates (Va/Vb). $C_{26}H_{36}O_7$. *p*-Toluenesulfonic acid, 0.07 g (0.40 mmol), was added to a solution of 1.0 g (2.42 mmol) of compound **IIIa**/**IIIb** in 10 ml of methylene chloride and 20 ml of methanol. The mixture was heated for 20 h under reflux and evaporated, and the residue was subjected to chromatographic separation using $CHCl_3$–MeOH as eluent. Yield of **Va**/**Vb** 0.40 g (36%), mp 75–79°C. IR spectrum, ν, cm^{-1}: 755, 1199, 1995, 1743, 2953, 3410. ^1H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.82 s and 0.83 s (6H, $C^{20'}H_3$), 1.06 m and 1.09 m (4H, 1′-H, 3′-H), 1.22 s (6H, $C^{19'}H_3$), 1.30 m (2H, 5′-H), 1.51 m (6H, 9′-H, 12-H, 12′-H), 1.52 s (6H, $C^{17'}H_3$), 1.61 m (2H, 12′-H), 1.76 m (2H, 1′-H), 1.82 m (2H, 7′-H), 1.92 m (4H, 2′-H, 6′-H), 2.00 m (4H, 6′-H), 2.15 m (8H, 3′-H, 11-H, 11′-H, 7′-H), 2.74 d (2H, 3-H, *J* = 8.0), 2.86 d (2H, 4-H, *J* = 8.0), 3.66 s and 3.67 s (12H, CH_3O), 4.97 s (2H, 5-H), 5.15 s (2H, 2-H), 5.94 s (2H, 6-H).

^{13}C NMR spectrum, δ_C, ppm: 13.92 q ($C^{20'}$), 17.72 q ($C^{17'}$), 19.26 t ($C^{2'}$), 20.46 t ($C^{12'}$), 22.46 t ($C^{11'}$), 27.95 t and 27.99 t ($C^{6'}$), 28.47 q and 28.60 q ($C^{19'}$), 34.02 t ($C^{3'}$), 36.96 t and 36.98 t ($C^{7'}$), 37.04 t and 37.16 t ($C^{1'}$), 39.53 s ($C^{4'}$), 43.59 s and 43.66 s ($C^{10'}$), 46.78 d and 46.81 d (C^4), 48.82 d (C^3), 52.02 q, 52.08 q, and 52.17 q (OCH_3), 55.32 d ($C^{5'}$), 81.07 d and 81.13 d (C^2), 82.57 d (C^5), 127.54 s and 127.63 s ($C^{9'}$), 127.69 d and 127.74 d (C^6), 138.92 s and 138.04 s ($C^{8'}$), 152.27 s and 152.30 s (C^1), 171.79 s and 171.97 s ($COOCH_3$), 183.92 s and 183.94 s ($C^{18'}$).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-8-[1-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4,10-dioxatricyclo[5.2.1.0^{2,6}]decane-3,5-diones (VIa/VIb). $C_{24}H_{32}O_6$. To a solution of 1.0 g (2.42 mmol) of isomer mixture **IIIa**/**IIIb** in 20 ml of ethyl acetate we added 0.10 g of 10% Pd/C, and the mixture was saturated with hydrogen and was stirred for 30 min at room temperature. The catalyst was filtered, the solvent was distilled off under reduced pressure, and the residue was ground with hexane. Yield of **VIa**/**VIb** 0.91 g (91%), mp 102–106°C. IR spectrum, ν, cm^{-1}: 855, 1154, 1229, 1592, 1724, 2874, 3420. ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.55 s (6H, $C^{20'}H_3$), 0.98 m (4H, 1′-H, 3′-H), 1.03 m (4H, 1′-H, 3′-H), 1.19 s and 1.20 s (6H, $C^{19'}H_3$), 1.24 m (4H, 5′-H), 1.48 m (2H, 2′-H) 1.83 m (14H, 1′-H, 2′-H, 6′-H, 7′-H, 9′-H, 12′-H), 1.95 m (4H, 6′-H), 2,14 m (6H, 3′-H, 11′-H), 2.39 m (2H, 7′-H), 3.08 d (2H, 2-H, *J* = 9.0), 3.36 d (2H, 6-H, *J* = 9), 4.41 s and 4.45 s (2H, 17′-H), 4.83 s (2H, 17′-H), 4.85 s (2H, 1-H), 4.90 s (2H, 7-H). ^{13}C NMR spectrum, δ_C, ppm: 13.98 q ($C^{20'}$), 19.71 t ($C^{2'}$), 22.50 t ($C^{12'}$), 22.60 t ($C^{11'}$), 25.85 t and 25.93 t ($C^{6'}$), 28.84 q ($C^{19'}$), 30.39 t and 30.60 t (C^9), 35.06 d and 35.14 d (C^8), 37.67 t and 37.69 t ($C^{3'}$), 38.46 t and 38.54 t ($C^{7'}$), 38.98 t and 39.02 t ($C^{1'}$), 40.37 s and 40.45 s ($C^{4'}$), 44.04 s ($C^{10'}$), 45.44 d and 45.58 d (C^2), 50.66 d and 50.71 d (C^6), 55.87 d and 56.11 d ($C^{9'}$), 56.17 d and 56.21 d ($C^{5'}$), 80.61 d and 80.64 d (C^7), 83.12 d and 83.33 d (C^1), 106.23 t and 106.29 t ($C^{17'}$), 147.79 s and 147.80 s ($C^{8'}$), 171.12 s and 172.04 s (C^3, C^5), 183.93 s and 183.96 s ($C^{18'}$).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4-(1-hydroxymethyl-2-methylpropyl)-10-oxa-4-azatricyclo[5.2.1.0^{2,6}]dec-8-ene-3,5-diones (VIIa/VIIb). $C_{29}H_{41}NO_6$. L-Valinol, 0.25 g (2.4 mmol), was added under argon to a solution of 1.0 g (2.42 mmol) of isomer mixture **IIIa**/**IIIb** in 45 ml of freshly distilled toluene, and the mixture was heated for 2 h under reflux. Triethylamine, 0.48 g (4.8 mmol), was added, and the mixture was refluxed for 17 h. The solvent was distilled off, and the residue was subjected to chromatographic separation using $CHCl_3$–MeOH (100 : 1 to 30 : 1) as eluent. Yield of **VIIa**/**VIIb** 0.68 g (56%). ^{1}H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.59 s (6H, $C^{20'}H_3$), 0.78 d (6H, $C^{4''}H_3$, *J* = 7), 0.98 d (6H, $C^{5''}H_3$, *J* = 7), 1.00 m (4H, 1′-H, 3′-H), 1.21 s (6H, $C^{19'}H_3$), 1.23 m (4H, 2′-H, 5′-H), 1.53 m (8H, 9′-H, 12′-H, 1′-H), 1.85 m (10H, 2′-H, 6′-H, 7′-H, 11′-H), 2.13 m (2H, 3′-H), 2.41 m (8H, 11′-H, 7′-H, 2″-H, 3″-H), 2.79 d (2H, 2-H, *J* = 6.5), 2.87 d (2H, 6-H, *J* = 6.5), 3.77 m (2H, 2OH), 3.98 d (4H, 1″-H), 4.38 s and 4.44 s (2H, 17′-H), 4.84 s (2H, 17′-H), 4.95 s and 4.97 s (2H, 1-H), 5.17 s (2H, 7-H), 6.00 s (2H, 9-H).

N-Substituted maleimides VIII–XVIII. *a*. Appropriate amine, 0.02 mol, was added to a solution of 0.02 mol of maleic anhydride in 80 ml of acetic acid, and the mixture was heated for 2–10 h under reflux (TLC). The solvent was removed under reduced pressure, and the residue was subjected to chromatography on silica gel. The product was additionally purified by recrystallization from diethyl ether or ethanol.

1-(3,4,5-Trimethoxybenzyl)-2,5-dihydro-1*H*-pyrrole-2,5-dione (IX). $C_{14}H_{15}NO_5$. Reaction time 2 h. Yield 31%. mp 128–130°C (from ethanol). UV spectrum, λ_{max}, nm ($\log\varepsilon$): 209 (4.38), 271 (3.12), 295 (2.81). IR spectrum, ν, cm^{-1}: 697, 839, 1132, 1239, 1593, 1710, 2845, 3092. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 3.75 s (3H, OCH_3), 3.79 s (6H, OCH_3), 4.53 s (2H, 5-H), 6.54 s (2H, 7-H, 11-H), 6.66 s (2H, 1-H, 2-H). ^{13}C NMR spectrum, δ_C, ppm: 41.47 t (C^5), 55.89 q (OCH_3), 60.53 q (OCH_3), 105.49 d (C^7, C^{11}), 131.64 s (C^6), 134.00 d (C^1, C^2), 137.39 s (C^9), 153.06 s (C^8, C^{10}), 170.20 s (C^3, C^4).

1-[2-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)ethyl]-2,5-dihydro-1*H*-pyrrole-2,5-dione (XVII). $C_{20}H_{27}NO_3$. Reaction time 10 h. Yield 43%. mp 114–115°C (from ether). UV spectrum, λ_{max}, nm ($\log\varepsilon$): 217 (4.27), 276 (3.39). IR spectrum, ν, cm^{-1}: 826, 1124, 1134, 1216, 1410, 1435, 1702, 3576. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 1.41 s [18H, $C(CH_3)_3$], 2.78 t (2H, 5-H, *J* = 9.0), 3.71 t (2H, 6-H, *J* = 9.0), 5.07 s (1H, OH), 6.64 s (2H, 1-H, 2-H), 6.96 s (2H, 8-H, 12-H). ^{13}C NMR spectrum, δ_C, ppm: 30.18 q [$C(\mathbf{C}H_3)_3$], 34.13 s [$\mathbf{C}(CH_3)_3$], 34.19 t (C^5), 39.29 t (C^6), 125.17 d (C^8, C^{12}), 129.29 s (C^9, C^{11}), 135.88 d (C^1, C^2), 135.94 s (C^7), 152.33 s (C^{10}), 170.44 s (C^3, C^4).

b. Appropriate amine, 11.39 g (5.3 mmol), was added at 0°C with stirring under a stream of argon to

a solution of 0.52 g (5.3 mmol) of maleic anhydride in 30 ml of methylene chloride. The mixture was kept for 16 h at room temperature with intermittent stirring, cooled to 0°C, one drop of DMF was added, and 0.53 ml (6.2 mmol) of oxalyl chloride was then added dropwise. The mixture was allowed to warm up to room temperature, stirred for 8 h, and purged with argon to remove excess oxalyl chloride. Triethylamine, 0.73 ml (5.3 mmol), was then added, and the mixture was left overnight. The resulting solution was washed with 1 M hydrochloric acid (2 × 10 ml) and dried over $MgSO_4$. The solvent was evaporated, the residue was dissolved in ethyl acetate, 0.2 g of charcoal was added, the mixture was refluxed for 30 min and filtered, and the filtrate was evaporated. The dark brown oily residue was dissolved in chloroform, and the solution was filtered through a layer of silica gel (8 g). The filtrate was evaporated, and the residue was crystallized from ether. We isolated 1.10 g (60%) of 1-[2-(3,5-di-*tert*-butyl-4-hydroxyphenyl)propyl]-2,5-dihydro-1*H*-pyrrole-2,5-dione (**XVIII**, $C_{21}H_{29}NO_3$) as light yellow crystals. Following method *a*, the reaction time was 10 h, and the yield of **XVIII** was 41%. mp 99–100°C (from ether). UV spectrum, λ_{max}, nm ($\log\varepsilon$): 217 (3.18), 278 (3.32). IR spectrum, ν, cm^{-1}: 826, 1119, 1132, 1152, 1226, 1704, 3596. ^1H NMR spectrum, δ, ppm (*J*, Hz): 1.42 s [18H, $2C(CH_3)_3$], 1.93 m (2H, 6-H), 2.54 t (2H, 5-H, *J* = 9.0), 3.57 t (2H, 7-H, *J* = 9.0), 5.01 s (1H, OH), 6.60 s (2H, 1-H, 2-H), 6.94 s (2H, 9-H, 12-H). ^{13}C NMR spectrum, δ_C, ppm: 29.67 s [**C**$(CH_3)_3$], 30.22 q [C(**C**$H_3)_3$], 32.85 t (C^6), 34.16 t (C^5), 37.74 t (C^7), 124.59 d (C^9, C^{13}), 131.33 s (C^{10}, C^{12}), 133.75 d (C^1, C^2), 135.74 s (C^8), 151.79 s (C^{11}), 170.67 s (C^3, C^4).

The cycloadducts of lambertianic acid (**I**) and maleimides were synthesized by the procedure described above for compounds **IIIa**/**IIIb**, method *d*. The overall yields and the *exo*/*endo*-isomer ratios are given in Table 2. The (1*R*,2*S*,6*R*,7*R*)/(1*S*,2*R*,6*S*,7*S*)- and (1*S*,2*S*,6*R*,7*S*)/(1*R*,2*R*,6*S*,7*R*)-diastereoisomer ratios were 1:1 in all cases (Table 2). Diastereoisomer mixtures **XXVIIa**/**XXVIIb**, **XXXIa**/**XXXIb**, **XXXIIa**/**XXXIIb**, **XXXIIIa**/**XXXIIIb**, **XXXVIIa**/**XXXVIIb**, **XXXVIIIa**/**XXXVIIIb**, and **XXXIXa**/**XXXIXb** and pure isomer **XLa** were isolated by column chromatography. Adducts **XIXa**/**XIXb**/**XXa**/**XXb** and **XXXVa**/**XXXVb**/**XXXVIa**/**XXXVIb** were converted into the corresponding methyl esters which were separated by column chromatography.

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-4-Benzyl-8-[18-carboxy-13,14,-15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.0^{2,6}]dec-8-ene-3,5-diones (XIXa/XIXb, XXa/XXb). $C_{31}H_{37}NO_5$. ^1H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz): 0.51 s (6H, $C^{20'}H_3$, **XXa**/**XXb**), 0.58 s (6H, $C^{20'}H_3$), 0.98 m (4H, 1′-H, 3′-H, **XXa**/**XXb**), 1.00 m (4H, 1′-H, 3′-H), 1.21 s (6H, $C^{19'}H_3$), 1.23 m (4H, 2′-H, 5′-H), 1.53 m (6H, 9′-H, 12′-H), 1.65 m (2H, 1′-H), 1.80 m (6H, 2′-H, 6′-H, 7′-H), 1.95 m (4H, 6′-H, 11′-H), 2.15 m (2H, 3′-H), 2.30 m (2H, 11′-H), 2.38 m (2H, 7′-H), 2.78 d (2H, 2-H, *J* = 6.5), 2.90 d (2H, 6-H, *J* = 6.5), 3.50 m (4H, 2-H, 6-H, **XXa**/**XXb**), 4.34 s and 4.35 s (2H, 17′-H, **XXa**/**XXb**), 4.39 s and 4.44 s (2H, 17′-H), 4.62 s (4H, CH_2), 4.78 s and 4.82 s (2H, 17′-H), 4.80 s and 4.84 s (2H, 17′-H, **XXa**/**XXb**), 4.51 s and 4.95 s (2H, 1-H, **XXa**/**XXb**), 4.96 s and 4.99 s (2H, 1-H), 5.19 s (2H, 7-H), 5.69 s (2H, 9-H, **XXa**/**XXb**), 5.98 s (2H, 9-H), 7.27 s (10H, H_{arom}).

The adducts were converted into the corresponding methyl esters following the procedure described in [23]. The *exo* and *endo* isomers were separated by column chromatography.

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4-(3,4,5-trimethoxybenzyl)-10-oxa-4-azatricyclo[5.2.1.0^{2,6}]dec-8-ene-3,5-diones (XXIa/XXIb, XXIIa/XXIIb). $C_{34}H_{43}NO_8$. UV spectrum: λ_{max} 270 nm ($\log\varepsilon$ 3.01). IR spectrum, ν, cm^{-1}: 753, 873, 1168, 1644, 1702, 2946. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.52 s and 0.53 s (6H, $C^{20'}H_3$, **XXIIa**/**XXIIb**), 0.57 s (6H, $C^{20'}H_3$), 0.96 m (4H, 1′-H, 3′-H), 1.19 s (6H, $C^{19'}H_3$), 1.23 m (4H, 2′-H, 5′-H), 1.50 m (6H, 9′-H, 12′-H), 1.82 m (10H, 1′-H, 2′-H, 6′-H, 7′-H, 11′-H), 2.06 m (2H, 3′-H), 2.26 m (2H, 11′-H), 2.38 m (2H, 7′-H), 2.80 d (2H, 2-H, *J* = 6.5), 2.91 d (2H, 6-H, *J* = 6.5), 3.49 m (4H, 2-H, 6-H, **XXIIa**/**XXIIb**), 3.77 s (18H, OCH_3, **XXIIa**/**XXIIb**), 3.79 s (18H, OCH_3), 4.27 s and 4.30 s (2H, 17′-H, **XXIIa**/**XXIIb**), 4.36 s and 4.38 s (2H, 17′-H), 4.56 s (4H, CH_2), 4.78 s (2H, 17′-H), 4.98 s and 5.00 s (2H, 1-H), 5.03 s and 5.04 s (2H, 1-H, **XXIIa**/**XXIIb**), 5.20 s (2H, 7-H), 5.64 s and 5.72 s (2H, 9-H, **XXIIa**/**XXIIb**), 6.00 s (2H, 9-H), 6.48 s (4H, 3″-H, 7″-H), 6.53 s and 6.54 s (4H, 3″-H, 7″-H, **XXIIa**/**XXIIb**).

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4-(4-carboxybutyl)-10-oxa-4-azatricyclo[5.2.1.0^{2,6}]dec-8-ene-3,5-diones (XXIIIa/XXIIIb, XXIVa/XXIVb). $C_{28}H_{37}NO_7$. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.54 s and 0.56 s (6H, $C^{20'}H_3$, **XXIVa**/**XXIVb**), 0.57 s and 0.58 s (6H, $C^{20'}H_3$), 1.02 m (4H, 1′-H, 3′-H), 1.20 s and 1.21 s (6H, $C^{19'}H_3$, **XXIVa**/**XXIVb**), 1.22 s and 1.23 s (6H,

$C^{19'}H_3$), 1.30 m (4H, 2′-H, 5′-H), 1.53 m (6H, 9′-H, 12′-H), 1.63 m (2H, 1′-H), 1.84 m (6H, 2′-H, 6′-H, 7-H), 1.86 m (4H, 2″-H), 1.95 m (4H, 6′-H, 11′-H), 2.22 m (2H, 3′-H), 2.30 m (2H, 11′-H), 2.31 t (4H, 1″-H), 2.36 m (2H, 7′-H), 2.77 d (2H, 2-H, *J* = 6.5), 2.87 d (2H, 6-H, *J* = 6.5), 3.50 m (4H, 2-H, 6-H, **XXIVa**/**XXIVb**), 3.53 t (4H, 3″-H, *J* = 6.5), 4.35 s and 4.45 s (2H, 17′-H, **XXIVa**/**XXIVb**), 4.42 s and 4.45 s (2H, 17′-H), 4.82 s (2H, 17′-H, **XXIVa**/**XXIVb**), 4.84 s and 4.85 s (2H, 17′-H), 4.95 s (2H, 1-H), 4.99 d and 5.04 d (2H, 1-H, *J* = 4.0, **XXIVa**/**XXIVb**), 5.16 s (2H, 7-H), 5.23 s (2H, 7-H, **XXIVa**/**XXIVb**), 5.90 s and 5.92 s (2H, 9-H, **XXIVa**/**XXIVb**), 5.98 d and 5.99 d (2H, 9-H, *J* = 1.2).

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4-carboxymethyl-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXVa/XXVb, XXVIa/XXVIb). $C_{26}H_{33}NO_7$. IR spectrum, ν, cm^{-1}: 756, 1176, 1648, 1713, 2941, 3434. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.53 s (6H, $C^{20'}H_3$, **XXVIa**/**XXVIb**), 0.56 s (6H, $C^{20'}H_3$), 1.01 m (4H, 1′-H, 3′-H), 1.26 s (6H, $C^{19'}H_3$), 1.23 m (4H, 2′-H, 5′-H), 1.24 s (6H, $C^{19'}H_3$, **XXVIa**/**XXVIb**), 1.52 m (8H, 1′-H, 9′-H, 12′-H), 1.84 m (10H, 1′-H, 2′-H, 6′-H, 7′-H), 2.10 m (4H, 3′-H, 11′-H), 2.37 m (2H, 7′-H), 2.97 d (2H, 2-H, *J* = 6.5), 3.00 d (2H, 6-H, *J* = 6.5), 3.28 s (4H, 1″-H), 3.58 m (4H, 2-H, 6-H, **XXVIa**/**XXVIb**), 4.30 s and 4.34 s (2H, 17′-H, **XXVIa**/**XXVIb**), 4.42 s and 4.45 s (2H, 17′-H), 4.81 s (2H, 17′-H, **XXVIa**/**XXVIb**), 4.84 s and 4.85 s (2H, 17′-H), 4.99 s (2H, 1-H), 5.09 s (2H, 1-H, **XXVIa**/**XXVIb**), 5.18 s (2H, 7-H), 5.24 s (2H, 7-H, **XXVIa**/**XXVIb**), 5.90 s and 5.92 s (2H, 9-H, **XXVIa**/**XXVIb**), 6.00 d (2H, 9-H, *J* = 1.2).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-4-[2-(*p*-Hydroxyphenyl)ethyl]-8-[18-carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo-[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXVIIa/XXVIIb). $C_{32}H_{39}NO_6$. mp 86–89°C. UV spectrum, λ_{max}, nm (log ε): 224 (2.98), 278 (2.24), 523 (2.13), 627 (2.13). IR spectrum, ν, cm^{-1}: 755, 881, 1165, 1648, 1692, 2942, 3423. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.57 s (6H, $C^{20'}H_3$), 1.01 m (4H, 1′-H, 3′-H), 1.20 s (6H, $C^{19'}H_3$), 1.28 m (4H, 2′-H, 5′-H), 1.50 m (6H, 9′-H, 12′-H), 1.62 m (2H, 1′-H), 1.82 m (6H, 2′-H, 6′-H, 7′-H), 1.96 m (4H, 6′-H, 11′-H), 2.13 m (2H, 3′-H), 2.30 m (2H, 11′-H), 2.38 m (2H, 7′-H), 2.74 m (6H, 2-H, CH_2N), 2.82 d and 2.87 d (2H, 6-H, *J* = 6.5), 3.63 t (4H, 2″-H, CH_2Ar, *J* = 7.5), 4.39 s and 4.45 s (2H, 17′-H), 4.83 s and 4.84 s (2H, 17′-H), 4.93 s and 4.95 s (2H, 1-H), 5.14 s (2H, 7-H), 5.96 d and 5.98 d (2H, 9-H, *J* = 1.2), 6.70 d (4H, 5″-H, 8″-H, *J* = 8.5), 7.03 d (4H, 4″-H, 9″-H, *J* = 8.5).

(1*S*,2*S*,6*R*,7*S*)- and (1*R*,2*R*,6*S*,7*R*)-4-[2-(*p*-Hydroxyphenyl)ethyl]-8-[18-carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo-[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXVIIIa/XXVIIIb). $C_{32}H_{39}NO_6$. ^1H NMR spectrum, δ, ppm (*J*, Hz) (the data were derived from the spectrum of isomer mixture **XXVIIa**/**XXVIIb**/**XXVIIIa**/**XXVIIIb**): 0.51 s (6H, $C^{20'}H_3$), 1.16 s (6H, $C^{19'}H_3$), 2.74 m (4H, CH_2N), 3.48 m (4H, 2-H, 6-H), 3.63 t (4H, CH_2Ar, *J* = 7.5), 4.33 s and 4.41 s (2H, 17′-H), 4.78 s and 4.81 s (2H, 17′-H), 5.01 d and 5.05 d (2H, 1-H, *J* = 4.0), 5.21 s (2H, 7-H), 5.87 s (2H, 9-H), 6.72 d (4H, 5″-H, 8″-H, *J* = 8.5), 7.02 d (4H, 4″-H, 9″-H, *J* = 8.5).

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4-[2-(*p*-methoxyphenyl)ethyl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXIXa/XXIXb, XXXa/XXXb). $C_{33}H_{41}NO_6$. UV spectrum, ν, λ_{max}, nm (log ε): 272 (2.32), 279 (2.29). IR spectrum, ν, cm^{-1}: 755, 881, 1246, 1647, 1706, 2941, 3423. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.52 s and 0.53 s (6H, $C^{20'}H_3$, **XXXa**/**XXXb**), 0.57 s (6H, $C^{20'}H_3$), 0.86 m (4H, 1′-H, 3′-H, **XXXa**/**XXXb**), 1.02 m (4H, 1′-H, 3′-H), 1.16 s (6H, $C^{19'}H_3$, **XXXa**/**XXXb**), 1.20 s (6H, $C^{19'}H_3$), 1.28 m (4H, 2′-H, 5′-H), 1.53 m (6H, 9′-H, 12′-H), 1.67 m (2H, 1′-H), 1.82 m (6H, 2′-H, 6′-H, 7′-H), 1.94 m (4H, 6′-H, 11′-H), 2.12 m and 2.13 m (2H, 3′-H), 2.29 m (2H, 11′-H), 2.37 m (2H, 7′-H), 2.75 d (2H, 2-H, *J* = 6.5), 2.70 t (4H, CH_2N, *J* = 7.5, **XXXa**/**XXXb**), 2.82 d and 2.87 d (2H, 6-H, *J* = 6.5), 2.85 t (4H, CH_2N, *J* = 7.5), 3.44 m and 3.46 m (4H, 2-H, 6-H, **XXXa**/**XXXb**), 3.52 t (4H, CH_2Ar, *J* = 7.5, **XXXa**/**XXXb**), 3.70 t (4H, CH_2Ar, *J* = 7.5), 3.80 s and 3.81 s (6H, OCH_3, **XXXa**/**XXXb**), 3.82 s (6H, OCH_3), 4.34 s and 4.42 s (2H, 17′-H, **XXXa**/**XXXb**), 4.38 s and 4.46 s (2H, 17′-H), 4.79 s and 4.82 s (2H, 13′-H, **XXXa**/**XXXb**), 4.83 s and 4.84 s (2H, 13′-H), 4.89 s and 4.92 s (2H, 1-H), 4.99 d and 5.03 d (2H, 1-H, *J* = 3.5, **XXXa**/**XXXb**), 5.11 s (2H, 7-H), 5.21 s (2H, 7-H, **XXXa**/**XXXb**), 5.88 s and 5.89 s (2H, 9-H, **XXXa**/**XXXb**), 5.95 d and 5.97 d (2H, 9-H, *J* = 1.2), 6.81 t (4H, 6″-H, 4″-H, *J* = 9.0, **XXXa**/**XXXb**), 6.83 t (4H, 6″-H, 4″-H, *J* = 9.0), 7.04 d.d (2H, 7″-H, *J* = 9.0, 1.0, **XXXa**/**XXXb**), 7.06 d.d (2H, 7″-H, *J* = 9.0, 1.0), 7.16 d.t (2H, 5″-H, *J* = 9.0, 1.0).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-4-Diphenylmethyl-8-[18-carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXXIa/XXXIb). $C_{37}H_{41}NO_5$. UV

spectrum: λ_{max} 258 nm (log ε 3.12). IR spectrum, ν, cm^{-1}: 700, 881, 1642, 1708, 2932, 3435. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.59 s (6H, $C^{20'}H_3$), 1.04 m (4H, 1′-H, 3′-H), 1.22 s and 1.24 s (6H, $C^{19'}H_3$), 1.30 m (4H, 2′-H, 5′-H), 1.56 m (6H, 9′-H, 12′-H), 1.64 m (2H, 1′-H), 1.85 m (6H, 2′-H, 6′-H, 7′-H), 1.99 m (4H, 6′-H, 11′-H), 2.06 m (2H, 3′-H), 2.30 m (2H, 11′-H), 2.38 m (2H, 7′-H), 2.77 d and 2.78 d (2H, 2-H, *J* = 6.5), 2.88 d (2H, 6-H, *J* = 6.5), 4.41 s and 4.45 s (2H, 17′-H), 4.85 s (2H, 17′-H), 5.02 s and 5.05 s (2H, 1-H), 5.24 s (2H, 7-H), 6.01 s and 6.02 s (2H, 9-H), 6.48 s (2H, CH), 7.28 m and 7.32 m (20H, H_{arom}).

(1*S*,2*S*,6*R*,7*S*)- and (1*R*,2*R*,6*S*,7*R*)-4-Diphenylmethyl-8-[18-carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXXIIa/XXXIIb). $C_{37}H_{41}NO_5$. ^1H NMR spectrum, δ, ppm: 0.53 s and 0.54 s (6H, $C^{20'}H_3$), 1.01 m and 1.03 m (4H, 1′-H, 3′-H), 1.21 s (6H, $C^{19'}H_3$), 1.25 m (4H, 2′-H, 5′-H), 1.56 m (6H, 9′-H, 12′-H), 1.64 m (2H, 1′-H), 1.85 m (6H, 2′-H, 6′-H, 7′-H), 1.99 m (4H, 6′-H, 11′-H), 2.06 m (2H, 3′-H), 2.30 m (2H, 11′-H), 2.38 m (2H, 7′-H), 3.54 m (4H, 2-H, 6-H), 4.24 s and 4.36 s (2H, 17′-H), 4.78 s and 4.84 s (2H, 17′-H), 4.99 s and 5.00 s (2H, 1-H), 5.20 s and 5.21 s (2H, 7-H), 5.72 s and 5.72 s (2H, 9-H), 6.32 s (2H, CH), 7.20 m, 7.22 m, and 7.27 m (20H, H_{arom}).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4-phenyl-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXXIIIa/XXXIIIb). $C_{30}H_{35}NO_5$. IR spectrum, ν, cm^{-1}: 691, 730, 1182, 1642, 1714, 2938, 3085. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.60 s (6H, $C^{20'}H_3$), 1.06 m (4H, 1′-H, 3′-H), 1.28 s (6H, $C^{19'}H_3$), 1.35 m (4H, 2′-H, 5′-H), 1.57 m (6H, 9′-H, 12′-H), 1.82 m (6H, 2′-H, 6′-H, 7′-H), 1.64 m (2H, 1′-H), 1.98 m (4H, 6′-H, 11′-H), 2.13 m (2H, 3′-H), 2.31 m (2H, 11′-H), 2.39 m (2H, 7′-H), 2.94 d (2H, 2-H, *J* = 6.5), 3.05 d (2H, 6-H, *J* = 6.5), 4.43 s and 4.49 s (2H, 17′-H), 4.86 s (2H, 17′-H), 5.08 s (2H, 1-H), 5.30 s (2H, 7-H), 6.05 s and 6.06 s (2H, 9-H), 7.40 m (10H, H_{arom}).

(1*S*,2*S*,6*R*,7*S*)- and (1*R*,2*R*,6*S*,7*R*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4-phenyl-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXXIVa/XXXIVb). $C_{30}H_{35}NO_5$. ^1H NMR spectrum, δ, ppm (the data were derived from the spectrum of isomer mixture **XXXIIIa**/**XXXIIIb**/**XXXIVa**/**XXXIVb**): 0.54 s and 0.55 s (6H, $C^{20'}H_3$), 1.20 s (6H, $C^{19'}H_3$), 3.67 m (4H, 2-H, 6-H), 4.45 s (2H, 17′-H), 4.72 s (2H, 17′-H), 5.13 s (2H, 1-H), 5.35 s (2H, 7-H), 6.05 s and 6.06 s (2H, 9-H), 7.40 m (10H, H_{arom}).

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-8-[18-Carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-4-(1-carboxy-2-phenylethyl)-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXXVa/XXXVb, XXXVIa/XXXVIb). $C_{33}H_{39}NO_7$. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.52 s and 0.55 s (6H, $C^{20'}H_3$, **XXXVIa**/**XXXVIb**), 0.57 s and 0.59 s (6H, $C^{20'}H_3$), 1.02 m (4H, 1′-H, 3′-H), 1.21 s and 1.15 s (6H, $C^{19'}H_3$, **XXXVIa**/**XXXVIb**), 1.23 s (6H, $C^{19'}H_3$), 1.25 m (4H, 2′-H, 5′-H), 1.52 m (6H, 9′-H, 12′-H), 1.63 m (2H, 1′-H), 1.80 m (6H, 2′-H, 6′-H, 7′-H), 1.95 m (4H, 6′-H, 11′-H), 2.13 m (2H, 3′-H), 2.22 m (2H, 11′-H), 2.65 d and 2.70 d (2H, 2-H, *J* = 6.5), 2.80 d (2H, 6-H, *J* = 6.5), 3.40 m (4H, 2″-H), 3.40 m (4H, 2-H, 6-H, **XXXVIa**/**XXXVIb**), 4.35 s and 4.40 s (2H, 17′-H), 4.41 s (2H, 17′-H, **XXXVIa**/**XXXVIb**), 4.82 s (2H, 17′-H), 4.89 m (2H, 1″-H), 5.00 s (2H, 1-H), 5.11 s (2H, 7-H), 5.21 d (2H, 7-H, *J* = 3.0, **XXXVIa**/**XXXVIb**), 5.68 s and 5.80 s (2H, 9-H, **XXXVIa**/**XXXVIb**), 5.92 d and 5.93 d (2H, 9-H, *J* = 1.2), 7.12 m (10H, H_{arom}), 7.21 m (10H, H_{arom}, **XXXVIa**/**XXXVIb**).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-4-[2-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)ethyl]-8-[18-carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXXVIIa/XXXVIIb). $C_{40}H_{55}NO_6$. UV spectrum, λ_{max}, nm (log ε): 276 (3.27), 301 (2.91), 368 (2.38). IR spectrum, ν, cm^{-1}: 885, 1169, 1646, 1702, 2957, 3449. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.59 s (6H, $C^{20'}H_3$), 1.03 m (4H, 1′-H, 3′-H), 1.22 s and 1.23 s (6H, $C^{19'}H_3$), 1.31 m (4H, 2′-H, 5′-H), 1.41 s [36H, $C(CH_3)_3$], 1.53 m (6H, 9′-H, 12′-H), 1.66 m (2H, 1′-H), 1.86 m (6H, 2′-H, 6′-H, 7′-H), 2.00 m (4H, 6′-H, 11′-H), 2.15 m (2H, 3′-H), 2.32 m (2H, 11′-H), 2.39 m (2H, 7′-H), 2.73 t (4H, CH_2N, *J* = 7.0), 2.74 d (2H, 2-H, *J* = 6.5), 2.84 d (2H, 6-H, *J* = 6.5), 3.65 t (4H, CH_2Ar, *J* = 7.0), 4.41 s and 4.47 s (2H, 17′-H), 4.85 s and 4.86 s (2H, 17′-H), 4.94 s and 4.97 s (2H, 1-H), 5.09 s (2H, OH), 5.15 s and 5.16 s (2H, 7-H), 5.98 d and 6.00 d (2H, 9-H, *J* = 1.2), 6.98 s (4H, 3″-H, 5″-H).

(1*S*,2*S*,6*R*,7*S*)- and (1*R*,2*R*,6*S*,7*R*)-4-[2-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)ethyl]-8-[18-carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXXVIIIa/XXXVIIIb). $C_{40}H_{55}NO_6$. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.53 s and 0.54 s (6H, $C^{20'}H_3$), 0.85 m (4H, 1′-H, 3′-H), 1.15 s and 1.17 s (6H,

$C^{19'}H_3$), 1.19 m (4H, 2′-H, 5′-H), 1.41 s [36H, $C(CH_3)_3$], 1.53 m (6H, 9′-H, 12′-H), 1.64 m (2H, 1′-H), 1.83 m (6H, 2′-H, 6′-H, 7′-H), 1.92 m and 2.20 m (4H, 6′-H, 11′-H), 2.12 m (2H, 3′-H), 2.35 m (2H, 11′-H), 2.54 m (2H, 7′-H), 2.73 t (4H, CH_2N, J = 7.0), 3.48 m (8H, 2-H, 6-H, CH_2Ar), 4.38 s and 4.44 s (2H, 17′-H), 4.82 s and 4.83 s (2H, 17′-H), 5.05 d and 5.06 d (2H, 1-H, J = 3.0), 5.09 s (2H, OH), 5.23 s and 5.24 s (2H, 7-H), 5.90 s (2H, 9-H), 6.95 s (4H, 3″-H, 5″-H).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-4-[3-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)propyl]-8-[18-carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XXXIXa/XXXIXb). $C_{41}H_{57}NO_6$. mp 87–89°C. UV spectrum: λ_{max} 277 nm ($\log\varepsilon$ 2.78). IR spectrum, ν, cm^{-1}: 881, 1121, 1648, 1702, 2956, 3449. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 0.59 s (6H, $C^{20'}H_3$), 1.03 m (4H, 1′-H, 3′-H), 1.20 s (6H, $C^{19'}H_3$), 1.30 m (4H, 2′-H, 5′-H), 1.41 s [36H, $C(CH_3)_3$], 1.53 m (6H, 9′-H, 12′-H), 1.65 m (6H, 1′-H, $CH_2C\mathbf{H}_2CH_2$), 1.87 m (6H, 2′-H, 6′-H, 7′-H), 2.00 m (4H, 6′-H, 11′-H), 2.15 m (2H, 3′-H), 2.23 m (2H, 11′-H), 2.39 m (2H, 7′-H), 2.50 t (4H, CH_2N, J = 7.0), 2.72 d (2H, 2-H, J = 7.0), 2.82 d and 2.83 d (2H, 6-H, J = 7.0), 3.51 t (4H, CH_2Ar, J = 7.0), 4.40 s and 4.46 s (2H, 17′-H), 4.84 s and 4.85 s (2H, 17′-H), 4.95 s and 4.95 s (2H, 1-H), 5.02 s (2H, OH), 5.02 s (2H, 7-H), 5.97 d and 5.99 d (2H, 9-H, J = 1.2), 6.94 s (4H, 3″-H, 5″-H).

(1*S*,2*S*,6*R*,7*S*)-4-[3-(3,5-Di-*tert*-butyl-4-hydroxyphenyl)propyl]-8-[18-carboxy-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]-dec-8-ene-3,5-dione (XLa). $C_{41}H_{57}NO_6$. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 0.57 s (3H, $C^{20'}H_3$), 1.02 m (2H, 1′-H, 3′-H), 1.20 s (3H, $C^{19'}$), 1.28 m (2H, 2′-H, 5′-H), 1.41 s [18H, $C(CH_3)_3$], 1.53 m (3H, 9′-H, 12′-H), 1.75 m (3H, 1′-H, $CH_2C\mathbf{H}_2CH_2$), 1.83 m (3H, 2′-H, 6′-H, 7′-H), 1.94 m (2H, 6′-H, 11′-H), 2.12 m (1H, 3′-H), 2.25 m (1H, 11′-H), 2.36 m (1H, 7′-H), 2.48 t (2H, CH_2N, J = 7.0), 3.33 m (2H, CH_2Ar), 3.45 d.d and 3.46 d.d (2H, 2-H, 6-H, J = 5.9, 2.8, 2.9), 4.44 s (1H, 17′-H), 4.83 s (1H, 17′-H), 5.06 d (1H, 1-H, J = 2.9, 1.7), 5.06 s (1H, OH), 5.22 d.q (1H, 7-H, J = 2.8, 1.7), 5.88 q (1H, 9-H), 6.93 s (2H, 5″-H, 8″-H).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-4-Benzyl-8-[18-methoxycarbonyl-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XLIa/XLIb). $C_{32}H_{39}NO_5$. mp 51–54°C. IR spectrum, ν, cm^{-1}: 881, 1152, 1177, 1645, 1704, 1774. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 0.48 s (6H, $C^{20'}H_3$), 1.02 m (4H, 1′-H, 3′-H), 1.02 s and 1.03 s (6H, $C^{19'}H_3$), 1.23 m (4H, 2′-H, 5′-H), 1.53 m (6H, 9′-H, 12′-H), 1.65 m (2H, 1′-H), 1.80 m (6H, 2′-H, 6′-H, 7′-H), 1.95 m (4H, 6′-H, 11′-H), 2.15 m (2H, 3′-H), 2.30 m (2H, 11′-H), 2.38 m (2H, 7′-H), 2.77 d and 2.78 d (2H, 2-H, J = 6.5), 2.87 d (2H, 6-H, J = 6.5), 3.58 s (6H, OCH_3), 4.39 s and 4.44 s (2H, 17′-H), 4.61 s (4H, CH_2), 4.78 s and 4.82 s (2H, 17′-H), 4.96 s and 4.99 s (2H, 1-H), 5.17 s (2H, 7-H), 5.97 d and 5.99 d (2H, 9-H, J = 1.2), 7.25 m (10H, H_{arom}).

(1*S*,2*S*,6*R*,7*S*)- and (1*R*,2*R*,6*S*,7*R*)-4-Benzyl-8-[18-methoxycarbonyl-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (XLIIa/XLIIb). $C_{32}H_{39}NO_5$. mp 48–50°C. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 0.42 s and 0.44 s (6H, $C^{16'}H_3$), 0.98 m (4H, 1′-H, 3′-H), 1.14 s (6H, $C^{14'}H_3$), 1.22 m (4H, 2′-H, 5′-H), 1.40 m and 1.46 m (6H, 9′-H, 12′-H), 1.61 m (2H, 1′-H), 1.72 m (10H, 1-H, 2′-H, 6-H, 7′-H, 11′-H), 1.92 m (2H, 3′-H), 2.23 m (2H, 11′-H), 2.34 m (2H, 7′-H), 3.47 d.d (4H, 2-H, 6-H, J = 7.6, 5.1, 5.0), 3.58 s (6H, OCH_3), 4.34 s and 4.35 s (2H, 17′-H), 4.35 d, 4.36 d, 4.46 d, and 4.48 s (4H, CH_2, J = 13.9, 13.8), 4.83 s and 4.84 s (2H, 17′-H), 4.98 d (2H, 1-H, J = 5.1), 5.18 d (2H, 7-H, J = 5.0), 5.68 s (2H, 9-H), 7.25 m (10H, H_{arom}).

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-4-Benzyl-8-[18-hydroxymethyl-13,14,15,16-tetranorlabd-8(17)-ene-12-yl]-10-oxa-4-azatricyclo[5.2.1.$0^{2,6}$]dec-8-enes (XLIIIa/XLIIIb, XLIVa/XLIVb). $C_{31}H_{43}NO_2$. Lithium aluminum hydride, 0.023 g (5.8 mmol), was added in small portions to a solution of 0.5 g (0.97 mmol) of adduct mixture **XLIa**/**XLIb**/**XLIIa**/**XLIIb** in 40 ml of anhydrous THF. The mixture was heated for 4 h under reflux and cooled to room temperature, a drop of water was carefully added, and the precipitate was filtered off and treated with two 20-ml portions of boiling chloroform. The combined extracts were filtered, dried over $MgSO_4$, and evaporated. The residue was subjected to column chromatography on Al_2O_3 to isolate 0.150 g (34%) of mixture **XLIIIa**/**XLIIIb**/**XLIVa**/**XLIVb**. ^{1}H NMR spectrum, δ, ppm (*J*, Hz): 0.63 s (6H, $C^{20'}H_3$, **XLIVa**/**XLIVb**), 0.68 s (6H, $C^{20'}H_3$), 0.95 m (4H, 1′-H, 3′-H, **XLIVa**/**XLIVb**), 0.98 m (4H, 1′-H, 3′-H), 0.96 s (6H, $C^{19'}H_3$), 1.25 m (4H, 2′-H, 5′-H), 1.48 m, 1.56 m, and 1.68 m (8H, 9′-H, 12′-H), 1.70 m, 1.72 m, 1.95 m, and 2.00 m (14H, 1′-H, 2′-H, 3′-H, 6′-H, 7′-H, 11′-H), 2.20 m, 2.28 m, 2.41 m, and 2.39 m (12H, 2-H, 3-H, 5-H, 6-H, 7′-H, 11′-H), 2.90 m (4H, 3-H, 5-H), 3.07 m (4H, 3-H, 5-H, **XLIVa**/**XLIVb**), 3.32 s (2H, 1-H), 3.42 s (2H, 1-H, **XLIVa**/**XLIVb**), 3.56 s (4H, $C\mathbf{H}_2OH$), 3.69 m and 3.71 m (2H, 7-H), 3.78 s and

3.80 s (2H, 7-H, **XLIVa**/**XLIVb**), 4.30 s and 4.34 s (2H, 17′-H, **XLIVa**/**XLIVb**), 4.42 s and 4.46 s (2H, 17′-H), 4.54 s (4H, CH_2), 4.74 s (2H, 17′-H), 4.79 s (2H, 17′-H, **XLIVa**/**XLIVb**), 5.80 d (2H, 9-H, J = 1.2, **XLIVa**/**XLIVb**), 5.94 s (2H, 9-H), 7.21 s, 7.29 s, 7.30 s (10H, H_{arom}).

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-8-[18-Acetoxymethyl-13,14,-15,16-tetranorlabd-8(17)-en-12-yl]-4-benzyl-10-oxa-4-azatricyclo[5.2.1.0^{2,6}]dec-8-enes (XLVa/XLVb, XLVIa/XLVIb). $C_{33}H_{45}NO_3$. Acetic anhydride, 0.5 ml, and pyridine, 1 ml, were added to 0.22 g (0.19 mmol) of adduct mixture **XLIIIa**/**XLIIIb**/**XLIVa**/**XLIVb**, and the resulting solution was left to stand overnight. The mixture was poured onto ice, and the products were extracted into chloroform (3 × 20 ml). The combined extracts were washed with water (4 × 20 ml), dried over $MgSO_4$, and evaporated, and the residue was subjected to column chromatography on aluminum oxide to isolate 0.050 g (46%) of mixture **XLVa**/**XLVb**/**XLVIa**/**XLVIb**. IR spectrum, ν, cm^{-1}: 895, 1065, 1251, 1730, 2954. ^{1}H NMR spectrum, δ, ppm (J, Hz): 0.65 s (6H, C$^{20'}$H$_3$, **XLVIa**/**XLVIb**), 0.69 s and 0.70 s (6H, C$^{20'}$H$_3$), 0.93 s and 0.94 s (4H, 19′-H), 0.98 m (4H, 1′-H, 3′-H), 1.24 m (4H, 2′-H, 5′-H), 1.49 m, 1.60 m, and 1.70 m (8H, 9′-H, 12′-H), 1.90 m and 1.97 m (14H, 1′-H, 2′-H, 3′-H, 6′-H, 7′-H, 11′-H), 2.00 s (6H, $COCH_3$), 2.20 m, 2.28 m, 2.39 m, and 2.41 m (12H, 2-H, 3-H, 5-H, 6-H, 7′-H, 11′-H), 2.90 m (4H, 3-H, 5-H), 3.09 m (4H, 3-H, 5-H, **XLVIa**/**XLVIb**), 3.58 s (4H, C**H**$_2$OH), 3.80 s (2H, 1-H), 3.85 s (2H, 1-H, **XLVIa**/**XLVIb**), 4.17 s, (2H, 7-H), 4.19 s (2H, 7-H, **XLVIa**/**XLVIb**), 4.31 s and 4.34 s (2H, 17′-H, **XLVIa**/**XLVIb**), 4.39 s and 4.43 s (2H, 17′-H), 4.54 s (4H, CH_2), 4.75 s (2H, 17′-H), 4.80 s (2H, 17′-H, **XLVIa**/**XLVIb**), 5.79 s and 5.80 s (2H, 9-H, **XLVIa**/**XLVIb**), 5.93 s (2H, 9-H), 7.23 m and 7.29 m (10H, H_{arom}). ^{13}C NMR spectrum, δ_C, ppm: 15.00 q (C$^{20'}$), 15.04 q (C$^{20'}$, **XLVIa**/**XLVIb**), 18.70 t (C$^{2'}$, **XLVIa**/**XLVIb**), 18.71 t (C$^{2'}$), 20.98 t (C^{12}), 21.25 t (C$^{12'}$, **XLVIa**/**XLVIb**), 24.21 t (C$^{6'}$), 25.93 t (C$^{11'}$, **XLVIa**/**XLVIb**), 26.23 t (C$^{11'}$), 27.34 q (C$^{19'}$, **XLVIa**/**XLVIb**), 27.37 q (C$^{19'}$), 35.93 t (C$^{3'}$, **XLVIa**/**XLVIb**), 35.96 t (C$^{3'}$), 37.09 t (C$^{7'}$), 38.23 t (C$^{1'}$), 38.24 t (C$^{1'}$, **XLVIa**/**XLVIb**), 38.67 t (CH_2), 39.29 s (C$^{4'}$, **XLVIa**/**XLVIb**), 39.37 s (C$^{4'}$), 44.36 d (C^2, **XLVIa**/**XLVIb**), 44.54 d (C^2), 45.27 d (C^6, **XLVIa**/**XLVIb**), 45.28 d (C^6), 47.11 q (OCH_3), 47.87 q (OCH_3, **XLVIa**/**XLVIb**), 55.90 d (C$^{9'}$, **XLVIa**/**XLVIb**), 55.93 d (C$^{9'}$), 56.00 d (C$^{5'}$), 56.43 d (C$^{5'}$, **XLVIa**/**XLVIb**), 56.98 t, 57.00 t, and 60.35 t (C^3, C^5, **XLVIa**/**XLVIb**), 57.07 t, 57.09 t, and 60.35 t (C^3, C^5), 66.54 t (C$^{18'}$), 66.55 t and 66.57 t (C$^{18'}$, **XLVIa**/**XLVIb**), 80.66 d (C^7), 81.25 d and 81.27 d (C^7, **XLVIa**/**XLVIb**), 82.25 d and 82.81 d (C^1), 82.64 d and 83.15 d (C^1, **XLVIa**/**XLVIb**), 106.50 t (C$^{17'}$), 106.56 t and 106.58 t (C$^{17'}$, **XLVIa**/**XLVIb**), 125.84 d and 126.61 d (C^9, **XLVIa**/**XLVIb**), 126.84 d and 127.39 d (C^9), 128.12 d, 128.13 d, 128.85 d, and 128.87 d (C$^{2''}$, C$^{3''}$, C$^{4''}$, C$^{5''}$, C$^{6''}$, **XLVIa**/**XLVIb**), 127.94 d, 128.24 d, and 128.34 d (C$^{2''}$, C$^{3''}$, C$^{4''}$, C$^{5''}$, C$^{6''}$), 147.37 s (C$^{8''}$), 147.56 s (C$^{8''}$, **XLVIa**/**XLVIb**), 151.05 s and 151.44 s (C^8, **XLVIa**/**XLVIb**), 151.50 s (C^8), 171.13 s (**C**OCH$_3$).

(1*R*,2*S*,6*R*,7*R*)-, (1*S*,2*R*,6*S*,7*S*)-, (1*S*,2*S*,6*R*,7*S*)-, and (1*R*,2*R*,6*S*,7*R*)-8-[18-Methoxycarbonyl-13,14,-15,16-tetranorlabd-8(17)-en-12-yl]-4-(3,4,5-trimethoxybenzyl)-10-oxa-4-azatricyclo[5.2.1.0^{2,6}]-dec-8-ene-3,5-diones (XLVIIa/XLVIIb, XLVIIIa/XLVIIIb). $C_{35}H_{45}NO_8$. ^{1}H NMR spectrum, δ, ppm (J, Hz): 0.44 s and 0.46 s (6H, C$^{20'}$H$_3$, **XLVIIIa**/**XLVIIIb**), 0.49 s (6H, C$^{20'}$H$_3$), 0.96 m (4H, 1′-H, 3′-H, **XLVIIIa**/**XLVIIIb**), 1.00 m (4H, 1′-H, 3′-H), 1.16 s (6H, C$^{19'}$H$_3$), 1.23 m (4H, 2′-H, 5′-H), 1.49 m (6H, 9′-H, 12′-H), 1.82 m (10H, 1′-H, 2′-H, 6′-H, 7′-H, 11′-H), 2.10 m (2H, 3′-H), 2.20 m (2H, 11′-H), 2.38 m (2H, 7′-H), 2.82 d (2H, 2-H, J = 6.5), 2.91 d (2H, 6-H, J = 6.5), 3.46 m (4H, 2-H, 6-H, **XLVIIIa**/**XLVIIIb**), 3.59 s (6H, OCH_3), 3.79 s (18H, OCH_3 in Ar), 3.80 s (18H, OCH_3, **XLVIIIa**/**XLVIIIb**), 4.30 s and 4.35 s (2H, 17′-H, **XLVIIIa**/**XLVIIIb**), 4.39 s and 4.43 s (2H, 17′-H), 4.56 s (4H, CH_2), 4.78 s (2H, 17′-H, **XLVIIIa**/**XLVIIIb**), 4.84 s (2H, 17′-H), 4.98 s and 5.00 s (2H, 1-H), 5.03 s and 5.04 s (2H, 1-H, **XLVIIIa**/**XLVIIIb**), 5.20 s (2H, 7-H), 5.64 s and 5.72 s (2H, 9-H, **XLVIIIa**/**XLVIIIb**), 6.00 s (2H, 9-H), 6.49 s (4H, 3″-H, 7″-H), 6.54 s and 6.55 s (4H, 3″-H, 7″-H, **XLVIIIa**/**XLVIIIb**).

(1*R*,2*S*,6*R*,7*R*)- and (1*S*,2*R*,6*S*,7*S*)-4-(1-Carboxy-2-phenylethyl)-8-[18-methoxycarbonyl-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo-[5.2.1.0^{2,6}]dec-8-ene-3,5-diones (XLIXa/XLIXb). $C_{35}H_{43}NO_7$. IR spectrum, ν, cm^{-1}: 700, 754, 1150, 1168, 1644, 1709, 1749, 1778, 2950. ^{1}H NMR spectrum, δ, ppm (J, Hz): 0.47 s (6H, C$^{20'}$H$_3$), 1.02 m (4H, 1′-H, 3′-H), 1.17 s (6H, C$^{19'}$H$_3$), 1.25 m (4H, 2′-H, 5′-H), 1.52 m (6H, 9′-H, 12′-H), 1.63 m (2H, 1′-H), 1.80 m (6H, 2′-H, 6′-H, 7′-H), 1.95 m (4H, 6′-H, 11′-H), 2.13 m (2H, 3′-H), 2.22 m (2H, 11′-H), 2.39 m (2H, 7′-H), 2.65 d and 2.70 d (2H, CH, J = 6.5), 2.79 d (2H, 6-H, J = 6.5), 3.40 d (2H, 2″-H, J = 6.0), 3.44 s (2H, 2″-H), 3.58 s (6H, OCH_3), 3.72 s and 3.75 s (6H, OCH_3), 4.38 s and 4.44 s (2H, 17′-H), 4.82 s (2H, 17′-H), 4.89 m (4H, 1″-H, 1-H), 4.99 s

(2H, 7-H), 5.93 s and 5.94 s (2H, 9-H), 7.12 m (10H, H_{arom}).

(1*S*,2*S*,6*R*,7*S*)- and (1*R*,2*R*,6*S*,7*R*)-4-(1-Carboxy-2-phenylethyl)-8-[18-methoxycarbonyl-13,14,15,16-tetranorlabd-8(17)-en-12-yl]-10-oxa-4-azatricyclo-[5.2.1.$0^{2,6}$]dec-8-ene-3,5-diones (La/Lb). $C_{35}H_{43}NO_7$. ^1H NMR spectrum, δ, ppm (*J*, Hz): 0.45 s (6H, $C^{20'}H_3$), 1.02 m (4H, 1′-H, 3′-H), 1.13 s and 1.15 s (6H, $C^{19'}H_3$), 1.25 m (4H, 2′-H, 5′-H), 1.52 m (6H, 9′-H, 12′-H), 1.63 m (2H, 1′-H), 1.80 m (6H, 2′-H, 6′-H, 7′-H), 1.95 m (4H, 6′-H, 11′-H), 2.13 m (2H, 3′-H), 2.22 m (2H, 11′-H), 2.39 m (2H, 7′-H), 3.40 m (8H, 2-H, 2″-H, 6-H), 3.58 s (6H, OCH_3), 3.72 s and 3.77 s (6H, OCH_3), 4.41 s (2H, 17′-H), 4.82 s (2H, 17′-H), 4.89 m (4H, 1-H, 1″-H), 5.12 s (2H, 7-H), 5.68 d and 5.80 d (2H, 9-H, *J* = 1.2), 7.07 m and 7.22 m (10H, H_{arom}).

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