Stereoselective Diazoalkane Cycloadditions to Chiral 5-Alkylidene-1,3-dioxan-4-ones and 3-Benzylidene-β-lactones

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Received 5 December 1997; revised 4 May 1998

Dedicated to Professor Dieter Seebach

Abstract: Stereoselective 1,3-dipolar cycloaddition of diazoalkanes to (*E*)-5-alkylidene-1,3-dioxan-4-ones **1** and the (*Z*)-isomers **(Z)-1** afforded spiropyrazolines **3** and **10**, respectively. The optically active 2-benzylidene-3-methyl-β-lactone **(8)** was synthesized from the corresponding 5-benzylidene-1,3-dioxan-4-one **1f** by hydrolysis and recyclization and added diazomethane with opposite stereodifferentiation. Photochemical elimination of nitrogen from spiropyrazolines **3** gave enantiomerically pure spirocyclopropanes **12** that could be further transformed to cyclopropanecarboxylic acids **13** and derivatives **14**.

Key words: diazoalkanes, 5-alkylidene-1,3-dioxan-4-ones, cycloaddition reactions, spiropyrazolines, spirocyclopropanes

Recently, the cycloaddition of diazomethane to 5-alkylidene-1,3-dioxan-4-ones **1**, derivatives of the naturally occurring polyhydroxybutyrates (PHB), was reported in a short communication.[1] Spiropyrazolines **3** were obtained with complete stereoselectivity, which could then lose N_2 affording spirocyclopropanes **12** or 5-alkylidene-1,3-dioxan-4-ones **15** by irradiation or thermolysis, respectively. In addition to detailed investigations and extension of these reactions to substituted diazoalkanes **2** ($R^3 \neq H$) and chemical transformations of the spirocyclopropanes **12**, we report here the possibility of changing the stereochemistry of the diazomethane cycloaddition (α versus β-attack) by the application of a corresponding 3-alkylidene-β-lactone **8**. The addition of diazomethane to (*E*)-5-alkylidene-1,3-dioxan-4-ones **1** gave β-products **3** (Scheme 1 and Table 1) with high stereoselectivity.[1] The same holds true for the addition of diazomethane to the (*Z*)-5-alkylidene-1,3-dioxan-4-one (*Z*)-**1a** (R^1 = Me, R^2= *t*-Bu) affording the diastereomer **10a** (Scheme 2 and Table 1). In the case of the less reactive 5-arylidene-1,3-dioxanones **1** and (*Z*)-**1** (R^1=Ph, 3-$MeOC_6H_4$) long reaction times were necessary (1 week) and mixtures of the diastereomeric spiropyrazolines **3** and **4** or **10** and **11** were obtained (Schemes 1 and 2), that could be separated by chromatography affording at least the major isomer in analytically pure state (Table 1). The configuration and constitution of the pyrazolines **3**, **4, 10** and **11** were elucidated by NMR spectroscopy (NOE-investigations included), and in some cases by their transformation to cyclopropanes **12** (vide infra). In addition, the structure of the cycloadduct **10b** was proved by X-ray crystal analysis (Figure).

In order to check the scope of the dipolar cycloaddition of diazoalkanes to 5-alkylidene-1,3-dioxan-4-ones **1**, diazoethane (R^3 = Me), trimethylsilyldiazomethane (R^3 = TMS) and ethyl diazoacetate ($R^3 = CO_2Et$) were included

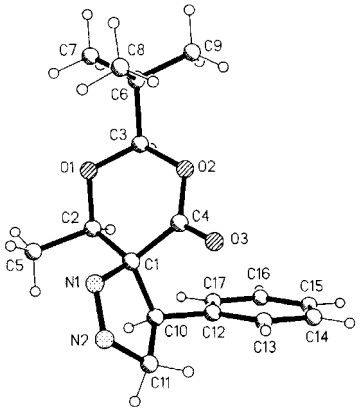
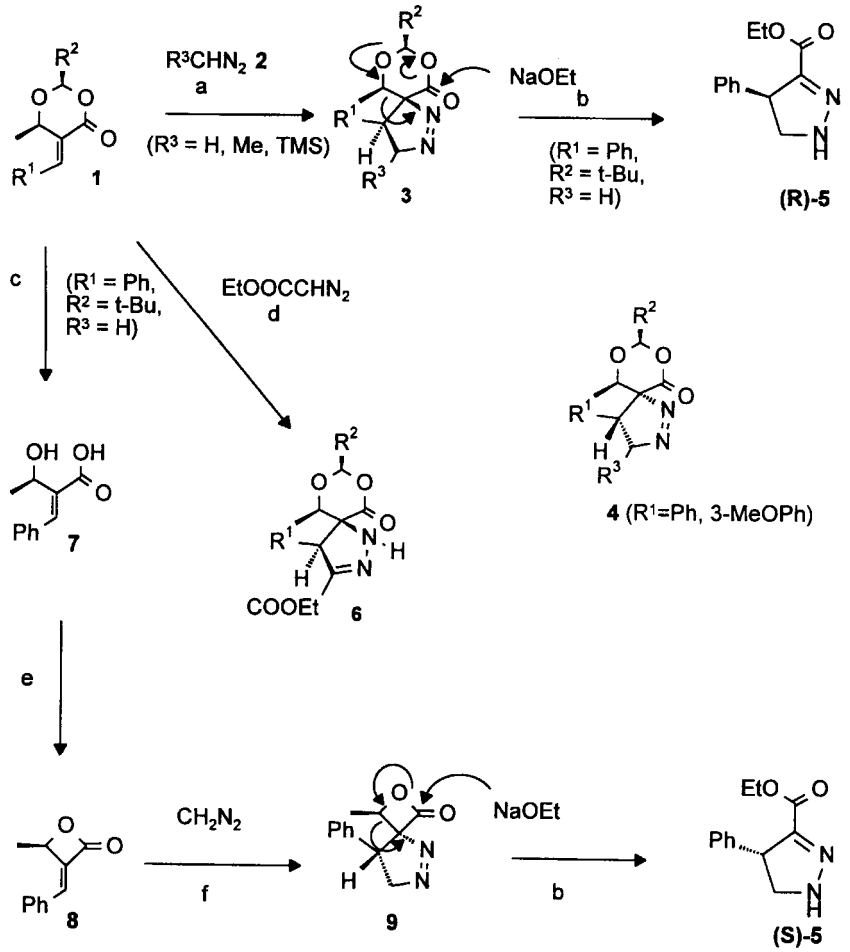


Figure. X-Ray Crystal Analysis of the Pyrazoline **10b**

in reactions with the ethylidene compound **1a**. Whereas diazoethane gave comparable results to diazomethane, reactions with trimethylsilyldiazomethane and ethyl diazoacetate proved more difficult to realize. Finally, high pressure conditions (10 kbar) or heating in benzene at 80°C afforded complete cycloadditions (Table 1) to the corresponding 1-pyrazolines **3** or 2-pyrazoline **6a**, respectively. The stereoselectivity was somewhat lower in these cases.

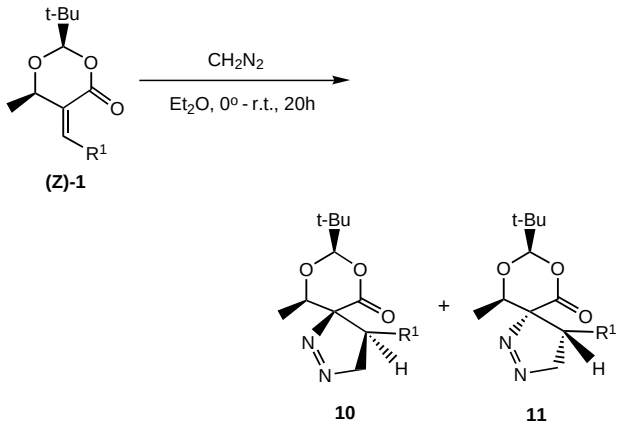
Since most of the spiropyrazolines **3** were obtained in high yields and in enantiomerically pure form, it was worthwhile utilizing them as precursors for new optically active cyclopropanecarboxylic acid derivatives. Attempts to eliminate N_2 by treatment with various metal salts such as CuCl, $CuCl_2 \cdot H_2O$, $Pd(OAc)_2$ or $Ce(NH_4)_2(NO_3)_6$ left **3** unchanged. Thermal elimination of N_2 from 1-pyrazolines **3** by heating in xylene to 130°C for 5 hours gave 5-alkylidene-1,3-dioxan-4-ones **15** (by 1,2 H-shift) in high yields, rather than the expected cyclopropanes.[1] These hitherto unknown products were formally derived from the aldol reaction of 1,3-dioxan-4-one with the corresponding ketone, but have not been synthesized in this way.[3] The envisaged transformation of pyrazolines **3** to spirocyclopropanes **12** could finally be achieved in high yields and excellent stereoselectivity by irradiation (330 nm).[1] Time-dependent absorption of the irradiation mixture of **3a** showed an isosbestic point. The configuration of the products **12** could be proved by NOE-experiments showing a positive NOE between the H-atom at position 6 of the dioxane ring and the methyl substituent (R^1 = Me)



1	R^1	R^2
a	Me	t-Bu
b	Me	c-Hex
c	Et	t-Bu
d	i-Pr	t-Bu
e	i-Pr	c-Hex
f	Ph	t-Bu
g	3-MeO-Ph	t-Bu

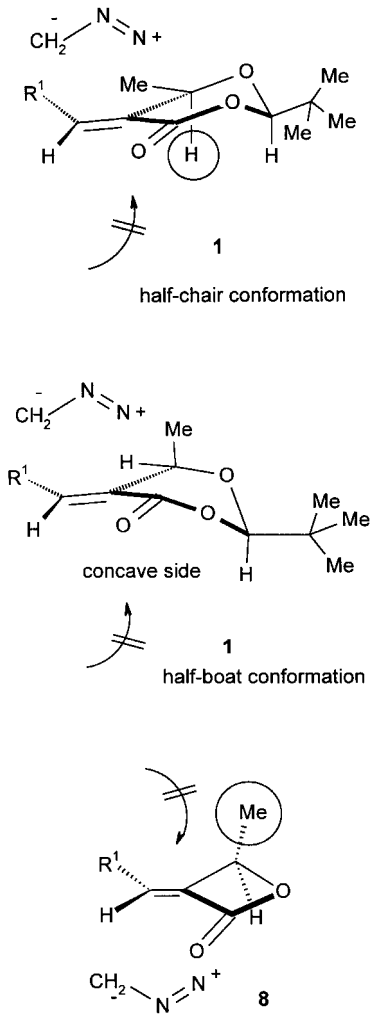
Reagents and conditions: a: Et_2O, 0 °C, 0 °C to r.t., 20 h (R^3 = H, Me) or benzene, reflux (R^3 = TMS); b: NaOEt/EtOH, r.t., 12 h; c: 3 N HCl/THF, r.t.; d: CH_2Cl_2, 10 kbar, 3 d; e: MesCl/CH_2Cl_2/$NaHCO_3$, 1 h, 0 °C, 3 h, r.t.; f: Et_2O, 0 °C to r.t., 20 h

Scheme 1



Scheme 2

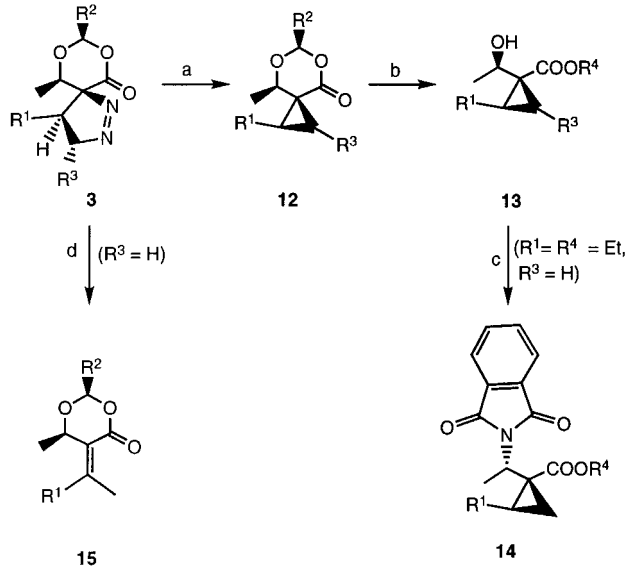
in the cyclopropane ring of compounds **12a** and **12c** derived from pyrazoline **3a** and **3c**. Since no signs of epimerization were observed during the photochemical transformation of spiropyrazolines **3** into spirocyclopropanes, a concerted mechanism is likely[4] rather than a two-step reaction. The spirocyclopropanes **12** can further be transformed to enantiopure cyclopropanecarboxylic acids or esters **13** by nucleophilic opening of the dioxanone ring by sodium hydroxide or, more efficiently by sodium alkoxides. Such hydroxyethylcyclopropanecarboxylates can serve as precursors in Mitsunobu reaction to enantiopure *β*-amino ester derivatives **14** in the cyclopropane series (Scheme 4); as an example, ester **13d** affords **14a**.



Scheme 3

Having established the synthetic utility of the spiropyrazolines **3**, we further approached spiropyrazolines in the β-lactone series, e.g. **8**, as synthetic equivalents of **1**. Thus, the 5-benzylidene-1,3-dioxan-4-one **1f** was hydrolysed to the corresponding (R)-α-(1-hydroxyethyl)cinnamic acid **(7)**, which could be cyclodehydrated to the benzylidene-β-lactone **8** with mesyl chloride in the presence of $NaHCO_3$. Enantiopure ylidene-β-lactones are rare.[5, 6] The only access reported is based on the separation of a racemate by Diels–Alder cycloaddition, separation of the resulting diastereomers and retro Diels–Alder reaction.[6] In the racemic methylidene-β-lactone series, the dipolar cycloaddition of diphenyldiazomethane was reported,[7] but it was not possible to investigate the stereoselectivity. The benzylidene-β-lactone **8** determines the stereochemical outcome of the cycloaddition. Reaction with diazomethane to **8** affords a quantitative yield of a single stereoisomer. The short reaction time of 12 hours, compared with 7 days in the analogous cycloaddition to the 5-benzylidene-1,3-dioxan-4-one **1f** (see above), demonstrates the higher reactivity of the ylidene-β-lactone **8** as compared to the corresponding dioxanones **1**. The configurations at the pyrazoline ring of the spiro-β-lactone **9** are opposite to those of the spiro-1,3-dioxanone **3i**. The absolute stereochemistry could be determined by the degradation of the *O*-heterocycle of **9**, or of the corresponding spirodioxanone **3i**, in the presence of sodium ethoxide. This degradation comprises nucleophilic attack at the lactone C-atom, retro-aldol reaction splitting of the hydroxyethyl moiety (presumably as acetaldehyde) and, in the case of the dioxanone **3i,** elimination of pivalaldehyde. In this way two enantiomers (***R***)-**5** and (***S***)-**5** are formed from **9** or **3i**, respectively. The cleavage is accompanied by some racemization, as seen from the optical rotation, which is lower in the latter case.

The change in stereodifferentiation of the cycloaddition of diazomethane to the ylidene-dioxanones **1** as compared to the ylidene-β-lactone **8** can be understood by conformational analysis. A half-chair conformation keeping the 6-H atom in an axial position, was deduced from NOE-investigations of a 2,6-dimethyl-5-methylidenedioxanone[2] and from energy minimization (PM3) of (*E*)-**1f** (see Scheme 3). This conformation with the methyl substituent in an equatorial position , however, suffers from unfavourable 1,3-allylic strain, which could be reduced by adopting a half-boat conformation (Scheme 3). In the former conformation the axial H-atom at position 6 hampers an attack from the bottom face. Thus, diazomethane preferably approaches the dioxanone from the top-face. The same directing effect would be exerted in the half-boat conformation where the bottom face is a concave side of a concave/convex-shaped molecule (Scheme 3). The ylidene-β-lactone **8** must exist in a 'square' shape (Scheme 3). The 4-methyl group and the 4-H-atom are



Reagents and conditions: a: hν/benzene; b: 10% aq HCl/THF, r.t., 20 h (R^4 = H) or NaOMe/MeOH, 0°C to r.t., 12 h (R^4 = Me) or K_2CO_3/EtOH, r.t. 20 h (R^4 = Et); c: DEAD/Ph_3P/Phthalimide/THF, 20 h; d: 130°C, 5 h

Scheme 4

Table 1. Spiropyrazolines **3**, **4**, **6**, **10**, and **11** Prepared

Product	R^1	R^2	R^3	Yield (%)/ Method	mp (°C)[a]	dr	$[\alpha]_{546}^{20}$ (*c* in g/100 mL $CHCl_3$	^{1}H NMR ($CDCl_3$/TMS), δ, *J* (Hz)	^{13}C NMR ($CDCl_3$/TMS) δ
3a	Me	*t*-Bu	H	99/A	oil	>95:5	–277.0 (1)[b]	0.93 (d, *J* = 7.4, 3 H, 1'-CH_3), 0.99 (s, 9 H, *t*-C_4H_9), 1.09 (d, *J* = 6.4, 3 H, 6-CH_3), 2.74 (qd, ^1J = 9.0, ^2J = 7.3, 1 H, CH-pyrazole), 4.11 and 4.93 (ABX, J_{AB} = 18.0, J_{AX} = 9.1, J_{BX} = 6.9, 2 H, CH_2-pyrazole), 4.13 (m, 1 H, 6-H), 5.10 (s, 1 H, 2-H)	13.4 (1'-CH_3), 16.1 (6-CH_3), 23.8 [C(CH_3)$_3$], 32.1 [*C*(CH_3)$_3$], 35.4 (CH-1'), 74.4 (CH-6), 85.9 (CH_2), 97.0 (C-5), 109.2 (CH-2), 167.5 (C=O)
3b	Me	*c*-Hex	H	98/A	oil	>95:5	–201.5 (2.5)	0.92 (d, *J* = 7.5, 1'-CH_3), 1.07–1.14 (m, 8 H, 5 H-*c*-Hex, 6-CH_3), 1.63–1.89 (m, 6 H, *c*-Hex), 2.73 (qd, ^1J = 7.3, ^2J = 9.0, 1'-H), 4.10 and 4.92 (ABX, J_{AB} = 17.9, J_{AX} = 6.9, J_{BX} = 9.1, 2 H, CH_2-pyrazole), 4.11 (m, 1 H, 6-H), 5.25 (d, *J* = 4.5, 1 H, 2-H)	13.4 (1'-CH_3), 16.1 (6-CH_3), 25.4 (CH_2-*c*-Hex), 26.2 (CH_2-*c*-Hex), 26.3 (CH_2-*c*-Hex), 32.0 (CH-1'), 42.2 (CH-*c*-Hex), 74.4 (CH-6), 86.0 (CH_2-pyrazole), 97.2 (C-5), 106.8 (CH-2), 167.4 (C=O)
3c	Me	*t*-Bu	Me	97/B	113–124	90:10	–127.2 (1.2)	0.97 (m, 6 H, 6-CH_3 and 1'-CH_3), 0.99 (s, 9 H, *t*-C_4H_9), 1.54 (d, *J* = 7.0, 3 H, CH_3-pyrazole), 2.30 (dq, ^1J = 9.3, ^2J = 7.4, 1 H, 1'-H), 3.94 (dq, ^1J = 9.3, ^2J = 7.0, 1 H, CH-pyrazole), 4.05 (q, *J* = 6.4, 1 H, 6-H), 5.11 (s, 1 H, 2-H)	11.1 (1'-CH_3), 15.6 (6-CH_3), 17.2 (CH_3-pyrazole), 23.8 [C(CH_3)$_3$], 35.4 [*C*(CH_3)$_3$], 39.0 (CH-1'), 74.3 (CH-6), 92.6 (CH-N), 98.3 (C-5), 109.3 (CH-2), 167.8 (C=O)
3d	Me	*t*-Bu	TMS	99/D 94/C	120–123	89:11 83:17	–	3.73 (d, *J* = 8.7, 1 H, CHSi), 0.10 [m, 9 H, $(CH_3)_3$Si], 0.94 (m, 15 H, *t*-C_4H_9, 6-CH_3, 1'-CH_3), 2.69 (qd, J_d = 8.5, J_q = 7.4, 1 H, 1'-H), 3.94 (q, *J* = 6.3, 1 H, 6-H), 5.05 (s, 1 H, 2-H)	–2.9 [$(CH_3)_3$Si], 13.5 (1'-CH_3), 15.6 (6-CH_3), 23.8 [C(CH_3)$_3$], 33.8 [(CH_3)$_3$*C*], 35.4 (CH-1'), 74.5 (CH-6), 93.4 (CH-Si), 96.9 (C-5), 109.0 (CH-2), 168.4 (C=O)
3e	Et	*t*-Bu	H	98/A	123.5–125	>95:5	–327.3 (2)	0.90 (t, *J* = 7.3, 3 H, 2'-CH_3), 1.00 (s, 9 H, *t*-C_4H_9), 1.01 (d, *J* = 6.6, 3 H, 6-CH_3), 1.10–1.42 (m, 2 H, 1'-CH_2), 2.54–2.65 (m, 1 H, CH-pyrazole), 4.02 and 4.93 (ABX, J_{AB} = 18.0, J_{AX} = 8.3, J_{BX} = 9.3, 2 H, CH_2-pyrazole), 4.12 (q, *J* = 6.6, 1 H, 6-H), 5.12 (s, 1 H, 2-H)	14.0 (2'-CH_3), 15.8 (6-CH_3), 21.1 (1'-CH_2), 23.8 [C(CH_3)$_3$], 35.4 [*C*(CH_3)$_3$], 39.6 (CH-1'), 74.2 (CH-6), 83.7 (CH_2-pyrazole), 96.7 (C-5), 109.2 (CH-2), 167.8 (C=O)
3f	*i*-Pr	*t*-Bu	H	97/A	100–111	>95:5	–99.6 (2.1)	0.91 [m, 9 H, CH(C*H*$_3$)$_2$, 6-CH_3], 1.00 (s, 9 H, *t*-C_4H_9), 1.49 (m, 1 H, 1'-CH), 2.55 (pseudo-q, *J* = 9.5, 1 H, CH-pyrazole), 3.83 and 4.88 (ABX, J_{AB} = 17.9, J_{AX} = 9.3, J_{BX} = 11.2, 2 H, CH_2-pyrazole), 4.12 (q, *J* = 6.4, 1 H, 6-H), 5.15 (s, 1 H, 2-H)	15.7 (6-CH_3), 23.6 [CH(*C*H$_3$)$_2$], 23.8 [C(CH_3)$_3$], 23.9 [CH(*C*H$_3$)$_2$], 26.4 [*C*H(CH$_3$)$_2$], 35.5 [*C*(CH_3)$_3$], 45.6 (CH-1'), 73.6 (CH-6), 81.5 (CH_2-pyrazole), 95.2 (C-5), 109.3 (CH-2), 167.9 (C=O)
3g	*i*-Pr	*c*-Hex	H	99/A	120–125	>95:5	–167.0 (1.2)	0.89–1.99 (m, 8 H, 6-CH_3 and 5 H of *c*-Hex), 1.20 (d, *J* = 8.2, 6 H; 2 × CH_3), 1.45 (m, 1 H, C*H*Me$_2$), 1.63–1.93 (m, 6 H, *c*-Hex), 2.60 (pseudo-q, *J* = 11.2, 1 H, 1'H), 4.13 (q, *J* = 6.4, 1 H, 6-H), 3.84 and 4.90 (ABX, J_{AB} = 17.9, J_{AX} = 9.3, J_{BX} = 11.2, 2 H, CH_2-pyrazole), 5.31 (s, 1 H, 2-H)	15.7 (6-CH_3), 22.7, 23.6 [CH(*C*H$_3$)$_2$], 25.5 (CH_2), 26.1 (CH_2), 26.2 (CH_2), 26.3 (CH_2), 26.5 [*C*H(CH$_3$)$_2$], 42.3 (CH-*c*-Hex), 45.5 (CH-1'), 73.8 (CH-6), 81.5 (CH_2-pyrazole), 95.5 (C-5), 107.0 (CH-2), 167.7 (C=O)

Table 1. (continued)

Product	R^1	R^2	R^3	Yield (%)/ Method	mp (°C)[a]	dr	$[\alpha]_{546}^{20}$ (*c* in g/100 mL $CHCl_3$)	^{1}H NMR ($CDCl_3$/TMS), δ, *J* (Hz)	^{13}C NMR ($CDCl_3$/TMS) δ
3h	*i*-Pr	*t*-Bu	Me	50/B	oil (R_f 0.4)	>95:5	–	0.95 [m, 9 H, 6-CH_3 and $CH(CH_3)_2$], 1.0 (s, 9 H, *t*-C_4H_9), 1.48 (m, 1 H, 2'-CH), 1.59 (d, *J* = 6.9, 3 H, CH_3-pyrazole), 2.10 (m, 1 H, 1'-H), 4.05 (q, *J* = 7.1, 1 H, 6-H), 4.10 (dq, ^1J = 9.5, ^2J = 7.2, 1 H, CH-pyrazole), 5.12 (s, 1 H, 2-H)	15.7 (1'-CH_3), 19.8 (CH_3-pyrazole), 22.0 [$CH(CH_3)_2$], 23.8 [$C(CH_3)_2$], 27.9 [$CH(CH_3)_2$], 34.5 [$C(CH_3)_3$], 52.4 (CH-1'), 73.8 (CH-6), 88.9 (CH-N), 96.9 (C-5), 109.4 (CH-2), 167.5 (C=O)
3i	Ph	*t*-Bu	H	53[c]/A	120–125 Et_2O/ pentane	≈50:50 (>95:5)[d]	–230.0 (1)	0.86 (d, *J* = 6.4, 3 H, 6-CH_3), 1.00 (s, 9 H, *t*-C_4H_9), 3.73 (q, *J* = 6.4, 1 H, 6-H), 3.98 (dd, ^1J = 6.3, ^2J = 8.9, 1 H, CH-pyrazole), 4.94 and 5.10 (ABX, J_{AB} = 18.0, J_{AX} = 8.9; J_{BX} = 6.3, 2 H, CH_2-pyrazole), 5.00 (s, 1 H, 2-H), 6.99–7.31 (m, 5 H, C_6H_5)	15.6 (6-CH_3), 23.8 [$C(CH_3)_3$], 35.4 [$C(CH_3)_3$], 44.5 (CH-1'), 74.9 (CH-6), 82.5 (CH_2-pyrazole), 98.4 (C-5), 109.2 (CH-2), 128.0, 128.4, 129.1 (CH_{arom}), 135.3 (C_{arom}), 167.1 (C=O)
3j	3-MeO-C_6H_4	*t*-Bu	H	48/A[e]	115–120	48:52	–202.0 (1)	0.86 (d, *J* = 6.4, 3 H, 6-CH_3), 0.96 (s, 9 H, *t*-C_4H_9), 3.11 (s, 3 H, OCH_3), 3.75 (q, *J* = 6.4, 1 H, 6-H), 3.98 (m, 1 H, CH-pyrazole), 4.96 (s, 1 H, 2-H), 4.90 and 4.99 (ABX, ^1J = 6.2, ^2J = 8.9, ^3J = 27.0, 1 H, CH_2-pyrazole), 6.48 (m, 2 H, C_6H_5), 6.75 (m, 1 H, C_6H_5), 7.20 (m, 1 H, (C_6H_5))	14.5 (6-CH_3), 22.6 [(CH_3)$_3$C], 34.2 [$C(CH_3)_3$], 43.3 (CH-1'), 54.1 (OCH_3), 73.6 (CH-6), 81.2 (CH_2-pyrazole), 97.1 (C-5), 107.9 (C-5), 107.9 (CH-2), 111.5, 113.5, 119.3, 129.0 (CH_{arom}), 135.7, 158.8 (C_{arom}), 165.9 (C=O)
4i	Ph	*t*-Bu	H	44/A[f]	118–125	≈50:50 (>95:5)[d]	189.0 (1)	0.74 (d, *J* = 6.5, 6-CH_3), 0.95 (s, 9 H, *t*-C_4H_9), 3.86 (dd, ^1J = 7.4, ^2J = 2.2, 1 H, CH-pyrazole), 4.95 (q, *J* = 6.5, 1 H, 6-H), 4.70–4.98 (m, 2 H, CH_2-pyrazole), 5.97 (s, 1 H, 2-H), 6.80–7.33 (m, 5 H, C_6H_5)	18.3 (6-CH_3), 24.2 [$C(CH_3)$]$_3$, 35.3 [$C(CH_3)_3$], 45.0 (CH-1'), 73.5 (CH-6), 86.1 (CH_2-pyrazole), 100.0 (C-5), 107.0 (CH-2), 128.4, 129.3 (CH_{arom}), 138.1 (C_{arom}), 166.0 (C=O)
4j	3-MeO-C_6H_4	*t*-Bu	H	29/A[g]	120–122	52:48 (>95:5)[d]	+343.0 (1)	0.78 (d, *J* = 6.4, 6-CH_3), 0.95 (s, 9 H, *t*-C_4H_9), 3.68 (s, 3 H, OCH_3), 3.67–3.75 (m, 1 H, CH-pyrazole), 4.73 (q, *J* = 6.4, 1 H, 6-H), 4.75–4.95 (m, 2 H, CH_2-pyrazole), 6.00 (s, 1 H, 2-H), 6.34 (m, 2 H, C_6H_5), 7.08 (m, 1 H, (C_6H_5)), 7.19 (m, 1 H, C_6H_5)	17.5 (6-CH_3), 22.8 [$C(CH_3)_3$], 34.0 [$C(CH_3)_3$], 43.5 (CH-1'), 54.2 (OCH_3), 72.0 (CH-6), 84.9 (CH_2-pyrazole), 100.0 (C-5), 105.5 (CH-2), 111.8, 113.0, 119.3, 129.0 (CH_{arom}), 138.5, 158.8 (C_{arom}), 164.5 (C=O)
6a	Me	*t*-Bu	CO_2Et	97/D	oil	89:11		0.89 (s, 9 H, *t*-C_4H_9), 1.20 (d, *J* = 6.3, 3 H, 6-CH_3), 1.23–1.29 (m, 6 H, 1'-CH_3, CH_3CH_2), 4.01 (q, *J* = 7.5, 1 H, 1'-H), 4.11 (q, *J* = 6.4, 1 H, 6-H), 4.21 (q, *J* = 5.8, 2 H, OCH_2), 4.94 (s, 1 H, 2-H), 6.65 (s, 1 H, NH)	10.8 (CH_3CH_2), 14.1 (1'-CH_3), 16.6 (6-CH_3), 23.6 [$C(CH_3)_3$], 35.1 [$(CH_3)_3C$], 44.5 (CH-1'), 61.2 (OCH_2), 73.2 (CH-6), 74.4 (C-5), 107.5 (CH-2), 145.3 (C=N), 161.5 (C=O), 169.3 (C=O)
10a	Me	*t*-Bu	H	73/A	120–130	>95:5	–332.1 (1)[b]	0.98 (s, 9 H, *t*-C_4H_9), 1.10 (d, *J* = 6.9, 3 H, 1'-CH_3), 1.20 (d, *J* = 6.5,3 H, 6-CH_3), 1.89 (m, 1 H, 1'-H), 3.94 (q, *J* = 6.5, 1 H, 6-H), 4.04 and 4.85 (ABX, J_{AB} = 17.1, J_{AX} = 8.6, J_{BX} 10.4, 2 H, CH_2-pyrazole), 5.03 (s, 1 H, 2-H)	11.7 (1'-CH_3), 14.2 (6-CH_3), 23.8 [$C(CH_3)_3$], 34.5 (CH-1), 35.5 [$C(CH_3)_3$], 76.9 (CH-6), 82.5 (CH_2-pyrazole), 97.7 (C-5), 109.3 (CH-2), 163.6 (C=O)

Table 1. (continued)

Product	R^1	R^2	R^3	Yield (%)/ Method	mp (°C)[a]	dr	$[\alpha]^{20}_{546}$ (*c* in g/100 mL $CHCl_3$	^{1}H NMR ($CDCl_3$/TMS), δ, *J* (Hz)	^{13}C NMR ($CDCl_3$/TMS) δ
10b	Ph	*t*-Bu	H	80[d]/A	180–181	80:20 (>95:5)[d]	–312.0 (0.5)	0.89 (s, 9 H, *t*-C_4H_9), 1.42 (d, *J* = 6.6, 3 H, 6-CH_3), 3.02 (dd, ^1J = 8.8, ^2J = 12.0, 1 H, 1'-H), 4.26 (q, *J* = 6.2, 1 H, 6-H), 4.63 (s, 1 H, 2-H), 4.78 and 5.16 (ABX, J_{AB} = 17.1, J_{AX} = 8.6, J_{BX} = 11.2, 2 H, CH_2-pyrazole), 7.20–7.21 (m, 5 H, C_6H_5)	18.3 (6-CH_3), 23.9 [C(CH_3)$_3$], 35.0 [*C*(CH_3)$_3$], 44.6 (CH-1'), 73.1 (CH-6), 85.7 (CH_2-pyrazole), 100.8 (C-5), 106.7 (CH-2), 127.9, 128.1, 128.9 (CH_{arom}), 137.8 (C_{arom}), 165.6 (C=O)
10c	4-MeO-C_6H_4	*t*-Bu	H	80/A	120–122	90:10 (>95:5)[d]	–424.6 (0.65)	0.86 (s, 9 H, *t*-C_4H_9), 1.37 (d, *J* = 6.6, 6-CH_3), 3.00 (m, 1 H, CH-pyrazole), 3.71 (s, 3 H, OCH_3), 4.21 (q, *J* = 6.6, 6-H), 4.63 (s, 1 H, 2 H), 4.78–5.10 (m, 2 H, CH_2-pyrazole), 6.74 (m, 3 H, C_6H_5), 7.18 (m, 1 H, C_6H_5)	14.9 (6-CH_3), 23.9 [C(CH_3)$_3$], 35.7 [*C*(CH_3)$_3$], 47.3 (CH-1'), 55.7 (OCH_3), 77.4 (CH-6) 81.1 (CH_2-pyrazole), 98.4 (C-5), 109.3 (CH-2), 113.7, 115.1, 121.5, 130.3 (CH_{arom}), 134.9, 160.3 (C_{arom}), 163.7 (C=O)
11b	Ph	*t*-Bu	H	A[h]	–	20:80	–	–	15.1 (6-CH_3), 24.0 [C(CH_3)$_3$], 35.5 [*C*(CH_3)$_3$], 43.0 (CH-1'), 75.2 (CH-6), 84.3 (CH_2-pyrazole), 98.5 (C-5); 111.2 (CH-2), 128.6, 128.9, 129.2 (CH_{arom}), 134.3 (C_{arom}), 163.9 (C=O)[i]

[a] Compounds melt with decomposition and formation of a gas.
[b] $[\alpha]^{20}_D$
[c] Together with 44% **4i**.
[d] After chromatography.
[e] Together with 29% **4j**.
[f] Together with 53% **3i**.
[g] Together with 48% **3j**.
[h] Could not be isolated in pure state.
[i] Obtained from a diastereomeric mixture of **10b** and **11b**.

symmetrically placed on each side of the ring. Thus, the larger methyl group hampers the attack from the β-face. These experiments show the possibility in principle of directing the cycloaddition of diazomethane either to the β- or to the α-face, depending on the type of 2-ylidene-3-hydroxybutyric acid derivative **1** or **8** used in the cycloaddition with diazomethane. Since **1** and **8** are synthetically equivalent, the products **12**, **13** and **14** obtained from **1** via **3** should be available with the opposite configuration in the cyclopropane ring starting from the β-lactone **8** via **9**.

^{1}H NMR and ^{13}C NMR spectra were recorded at 300 and 75.5 MHz, respectively on a Bruker AC-300 with TMS as internal standard. Diastereomeric ratios were determined by NMR and in part by analytical HPLC (Kontron Instruments) on RP 18 (Licrosphere, Hewlett-Packard; d = 4.5 mm, l = 20 cm, MeCN; 1 mL / min). Optical rotation was determined with a Perkin-Elmer polarimeter 241 at 20 °C. MS (HP 5995 A) and HRMS (MAT 711, Varian) were measured at 70eV. For preparative column chromatography, silica gel (0.04–0.063 mm, Merck) was used. An immersion reactor with Hg high-pressure lamp from Heraeus Noblelight (150 W) was used for photochemical elimination of N_2.

Starting materials **1** were obtained in a known way starting from (*R*)-polyhydroxybutyrate (donated from Zeneca Biopolymers), depolymerization,[8] establishment of the dioxanone ring[9] and final two-step aldol condensation.[3] For analytical data of new compounds **1b** and **1e,** see below. Diazomethane was generated from a mixture of Diazald (Aldrich), EtOH, KOH and Et_2O by distillation.[10]

(2S,5R)-(E)-2-Cyclohexyl-5-ethylidene-6-methyl-1,3-dioxan-4-one **(1b)**: colorless oil; yield: 33%; R_f 0.45 (hexane/Et_2O, 5:1).
^{1}H NMR ($CDCl_3$): δ = 0.97–1.18 (m, 6 H, 3 CH_2 *c*-hex), 1.25 (d, *J* = 6.4 Hz, 3 H, 6-CH_3), 1.27–1.76 (m, 5 H, 2 CH_2 *c*-hex, 2-CH), 1.71 (d, *J* = 7.4 Hz, 3 H, 1'-CH_3), 3.35 (q, *J* = 7.0 Hz, 1 H, 6-H), 4.78 (d, *J* = 5.2 Hz, 1 H, 2-H), 6.71 (q, *J* = 7.4 Hz, 1 H, 1'-H).
^{13}C NMR ($CDCl_3$): δ =14.3 (CH_3), 20.6 (CH_3), 25.4 (CH_2), 26.1 (CH_2), 26.4 (CH_2), 41.2 (CH), 71.5 (CH-6), 102.6 (CH-2), 131.6 (C-5), 138.4 (CH-1'), 166.4 (C=O).

(2S,5R)-(E)-2-Cyclohexyl-5-Isobutylidene-6-methyl-1,3-dioxan-4-one **(1e)**: colorless oil; yield: 37%; R_f 0.5 (hexane/Et_2O, 5:1); $[\alpha]_{546}$ 102.4 (*c* = 1.9, $CHCl_3$).
^{1}H NMR ($CDCl_3$): δ = 0.98 [dd, 6 H, CH(C*H*$_3$)$_2$], 1.02–1.29 (m, 6 H, 3 × CH_2-cyclohexyl), 1.31 (d, *J* = 6.4 Hz, 3 H, 6-CH_3), 1.49–1.81 (m, 5 H, 2 × CH_2-cyclohexyl, CH), 2.43–2.49 (m, 1 H, CH), 4.80 (m, 1 H, 6-H), 4.83 (d, *J* = 5.2 Hz, 1 H, 2-H), 6.46 (d, *J* = 11.3 Hz, 1 H, 1'-H).
^{13}C NMR ($CDCl_3$): δ = 21.4 and 22.0 [CH(*C*H_3)$_2$], 22.1 (6-CH_3), 25.5 (2 × CH_2), 26.2 (CH_2), 26.4 (CH_2), 26.5 (CH_2), 27.8 (CH-2'), 41.3 (=CH), 71.5 (CH-6), 102.7 (CH-2), 128.1 (C-6), 149.8 (CH-1'), 166.9 (C=O).

Spiropyrazolines 3, 4, 6, **10 and 11 by Addition of Diazoalkanes to 5-Alkylidene-1,3-dioxanones 1 and (*Z*)-1; General Procedures:**
a) Diazomethane
A 1 M solution of CH_2N_2 in Et_2O was prepared from *N*-methyl-*N*-nitroso-4-toluenesulfonamide (Diazald®) in the distillation set "Diazald-Kit" (Aldrich).

b) Diazoethane
A 40% aq KOH (9 mL) was immersed in Et_2O (30 mL). At 0 °C *N*-ethyl-*N*-nitrosourea[11] (3.5 g, 30 mmol) was added in small portions

Table 2. Spirocyclopropanes **12**, Cyclopropanecarboxylic Acids **13** and Esters **14** Prepared

Product	R^1	R^2	R^3	R^4	Yield (%)	$[a]_{546}$ (*c* in g/100 mL $CHCl_3$)	^{1}H NMR ($CDCl_3$/TMS) δ, *J* (Hz)	^{13}C NMR ($CDCl_3$/TMS) δ
12a	Me	*t*-Bu	H	–	99	+ 67.1 (2.25)	0.63 and 1.73 (ABX, J_{AB} = 4.9, J_{Ax} = 6.7, J_{Bx} = 9.3, 2H, Pr), 0.95 (s, 9H, *t*-C_4H_9), 1.10 (d, *J* = 6.4, 3H, 1-CH_3), 1.18 (d, *J* = 6.3, 3H, 6-CH_3), 1.48 (m, 1H, CH-c-Pr), 4.00 (q, *J* = 6.3, 1H, 6-H), 4.92 (s, 1H, 2-H)	13.3 (*C*H_3-*c*-Pr), 18.9 (CH_2-*c*-Pr), 21.6 (6-CH_3), 23.8 (CH-*c*-Pr, 24.0 [C(CH_3)$_3$], 28.2 (C-5), 34.7 [(CH_3)$_3$*C*], 70.8 (CH-6), 105.7 (CH-2), 173.6 (C=O)
12b	Me	*c*-Hex	H	–	98	+ 83.7 (1.78)	0.55 (dd, ^1J = 4.9, ^2J = 6.7, 1H, CH_2-*c*-Pr), 1.07 (d, *J* = 6.4, 3H, CH_3), 1.15 (d, *J* = 6.3, 3H, 6-CH_3), 1.10–1.22 (m, 5H, CH_2-*c*-Hex), 1.40–1.81 (m, 7H, 5H-CH_2-*c*-Hex, 1H-CH-*c*-Hex, 1H-CH_2-*c*-Pr), 3.97 (q, *J* = 6.3, 1H, 6-H), 5.04 (d, *J* = 5.0, 1H, 2-H)	13.2(CH_3), 18.7 (CH_2-*c*-Pr), 21.6 (CH_3), 23.8 (CH-*c*-Pr), 25.5 (CH_2), 25.6 (CH_2), 26.2 (CH_2), 26.5 (CH_2), 28.3 (C-5), 41.6 (CH-*c*-Hex), 70.8 (CH-6), 103.2 (CH-2), 173.2 (C=O)
12c	Me	*t*-Bu	Me	–	98	–	0.90 (s, 9H, *t*-C_4H_9), 0.96 (m, 1H, *c*-Pr), 1.10 (d, *J* = 6.4, 3H, C*H*$_3$-*c*-Pr), 1.16 (d, *J* = 6.3, 3H, 6-CH_3), 1.33 (d, *J* = 6.3, 1H, H-*c*-Pr), 1.41 (m, 1H, H-*c*-Pr), 3.88 (q, *J* = 6.3, 1H, 6-H), 4.89 (s, 1H, 2-H)	12.6 (CH_3), 13.0 (CH_3), 21.1 (6-CH_3), 23.9 [C(CH_3)$_3$], 27.1 (CH-*c*-Pr), 9.6 (CH-*c*-Pr), 32.2 (C–5), 34.6 [(CH_3)$_3$*C*], 71.8 (CH-6), 105.4 (CH-2), 172.0 (C=O)
12d	Me	*t*-Bu	TMS	–	42	+ 114.8 (0.5)	0.07 [s, 9H, Si(CH_3)$_3$], 0.89 (m, 1H, CHSi), 0.94 (s, 9H, *t*-C_4H_9), 1.20 (d, *J* = 6.2, 3H, 6-CH_3), 1.22 (d, *J* = 5.4, 3H, C*H*$_3$-*c*-Pr), 1.31 (m, 1H, CH-*c*-Pr), 3.90 (q, *J* = 6.3, 1H, 6-H), 4.90 (s, 1H, 2-H)	–0.43 [Si(CH_3)$_3$], 15.3 (*C*H_3-*c*-Pr), 20.0 (CHSi), 22.2 (6-CH_3), 24.0 [C(*C*H_3)$_3$], 27.6 (CH-*c*-Pr), 33.8 (C), 34.4 (C), 71.1 (CH-6), 104.6 (CH-2), 173.4 (C=O)
12e	Et	*t*-Bu	H	–	99	+ 109.2 (1.64)	0.60 and 1.67 (ABX, J_{AB} = 5.0, J_{Ax} = 9.4, J_{Bx} = 6.2, 2H-*c*-Pr), 0.92 (s, 9H, *t*-C_4H_9), 1.00 (pseudo-t, *J* = 7.0, 2H, CH_2), 1.15 (d, *J* = 6.3, 3H, 6-CH_3), 1.28–1.35 (m, 4H, CH_3, CH-*c*-Pr), 3.97 (q, *J* = 6.3, 1H, 6-H), 4.90 (s, 1H, 2-H)	13.7 (CH_3), 17.8 (CH_2-*c*-Pr), 21.6 (6-CH_3), 21.7 (CH_2), 23.9 [C(*C*H_3)$_3$], 28.5 (C-5), 31.5 (CH-*c*-Pr), 34.7 [(CH_3)$_3$*C*], 70.9 (CH-6), 105.6 (CH-2), 173.6 (C=O)
12f	*i*-Pr	*t*-Bu	H	–	99	+ 80.7 (1)	0.62 and 1.65 (ABX, J_{AB} = 5.0, J_{Ax} = 7.7, J_{Bx} = 4.9, 2H-*c*-Pr), 0.92 (s, 9H, *t*-C_4H_9), 1.00 (*d*, *J* = 3.1, 6H, CH(C*H*$_3$)$_2$], 1.15 (d, *J* = 6.2, 3H, 6-CH_3), 1.32 (m, 1H, CH), 1.51 (m, 1H, CH), 4.02 (q, *J* = 6.2, 1H, 6-CH), 4.97 (s, 1H, 2-CH)	17.5 (CH_2-*c*-Pr), 21.8 (6-CH_3), 22.3 [(*C*H_3)$_2$], 23.8 [C(*C*H_3)$_3$], 27.8 [(CH_3)$_2$*C*H], 29.0 C-5, 34.6 [(CH_3)$_3$*C*], 37.8 (CH-*c*-Pr), 70.7 (CH-6), 105.4 (CH-2), 173.4 (C=O)
12g	Ph	*t*-Bu	H	–	77	+ 13.5 (2)	0.88 (d, *J* = 6.3, 3H, 6-CH_3), 0.93 (s, 9H, *t*-C_4H_9), 1.48 and 1.98 (ABX, J_{AB} = 5.5, J_{Ax} = 9.4, J_{Bx} = 7.2, 2H, CH_2-*c*-Pr), 2.85 (dd, J^{AX} = 9.0, J^{BX} = 7.2, CH-*c*-Pr), 3.65 (q, *J* = 6.3, 1H, 6-H), 4.90 (s, 1H, 2-H), 7.15–7.29 (m, 5H, (C_6H_5)	15.5 (CH_2), 20.4 (6-CH_3), 23.9 [C(*C*H_3)$_3$], 30.6 (C-5), 32.9 (CH-*c*-Pr), 34.8 [(CH_3)$_3$*C*], 71.1 (CH-6), 106.4 (CH-2), 127.5, 128.7, 129.2 (CH_{arom}), 134.5 (Caron), 172.6 (C=O)

Table 2. (continued)

Product	R^1	R^2	R^3	R^4	Yield (%)	$[a]_{546}$ (*c* in g/100 mL $CHCl_3$)	^{1}H NMR ($CDCl_3$/TMS) δ, *J* (Hz)	^{13}C NMR ($CDCl_3$/TMS) δ
13a	Ph	*t*-Bu[a]	H	H	66	–39.0 (2)	1.17 and 1.83 (ABX, J_{AB} = 5.1, J_{Ax} = 7.2, J_{Bx} = 9.1, 2H, CH_2-*c*-Pr), 1.35 (d, *J* = 6.6, 3H, CH_3), 2.97 (m, 2H, CHO, C*H*Ph), 7.23–7.33 (m, 5H, C_6H_5)	16.9 (CH_2), 21.1 (CH_3), 33.9 (*C*HPh), 34.2 (C-1), 67.4 (CHO), 127.4, 128.4, 129.6 (CH_{arom}), 135.4 (C_{arom}), 178.7 (C=O)
13b	Me	*c*-Hex[a]	H	H	40	+ 6.1 (1)	0.41 (dd, ^1J = 3.5, ^2J = 6.0, 1H, H-*c*-Pr), 1.26 (d, *J* = 5.8, 3H, 2-CH_3), 1.43 (d, *J* = 6.5, 3H, CH_3), 1.53–1.58 (m, 2H, H-*c*-Pr, 2-H), 3.42 (m 1H, CHO)	13.3 (2-CH_3), 21.1 CH_2), 21.2 (CH_3), 32.1 (C–1), 68.0 (CHO), 180.4 (C=O)
13c	Ph	*t*-Bu[a]	H	Me	73	–64.0 (3.9)	1.11 and 1.74 (ABX, J_{AB} = 5.0, J_{Ax} = 7.3, J_{Bx} = 9.0, 2 x 1H-*c*-Pr), 1.34 (d, *J* = 6.6, 3H, CH_3), 2.90 (m, 1H, 2-H), 3.02 (m, 1H, 1´-H), 3.75 (s, 3H, CH_3O), 7.23–7.34 (m, 5H, C_6H_5)	16.9 (CH_2), 21.4 (1'-CH_3), 33.0 (2-CH), 34.4 (C-1), 67.6 (CH-1), 126.1, 128.6, 128.7 (CH_{arom}), 135.8 (C_{arom}), 174.5 (C=O)
13d	Et	*t*-Bu[a]	H	Et	75	-	0.29 (dd, ^1J = 5.5, ^2J = 3.51H, H-*c*-Pr), 1.01 (t, *J* = 7.2, 3H, CH_3), 1.19 (t, *J* = 7.1, 3H, CH_3), 1.35 (d, *J* = 6.5, 3H, CH_3), 1.36 (m, 2H, 2-CH_2), 1.41 (m, 1H, 2-H), 1.62 (m, 1H, H-*c*-Pr), 3.28 (q, *J* = 6.4, 1H, CHO), 3.44 (br, 1H, OH), 4.07 (dq, ^1J = 7.2, ^2J = 4.8, 2H, CH_2-O)	–
14a	Et	–	H	Et	50[b]	–20.3 (2.25)	0.54 (dd, *J* = 4.7, 6.6, 1H, H-*c*-Pr), 1.01 (t, *J* = 7.2, 3H, CH_3), 1.21 (t, *J* = 7.1, 3H, CH_3), 1.25–1.42 (m, 3H, 2-CH_2, 2-H), 1.68 (m, 1H, H-*c*-Pr), 1.73 (d, *J* = 7.3, 3H, 1'-CH_3), 4.02 (q, *J* = 7.3, 1H, 1'-CH_3), 4.02 (q, *J* = 7.3, 1H, 1'-H), 4.10 (q, *J* = 7.0, 2H, CH_2O, 7.62 (d, *J* = 3.1, 1H, C_6H_5), 7.72 (d, *J* = 3.1, 1H, C_6H_5, Ph), 7.73 (d, *J* = 3.1, 1H, C_6H_5)	13.9 (CH_3), 14.1 (CH_3), 17.8 (CH_3N), 18.6 (CH_2), 21.6 (CH_2), 30.3 (CH-2), 31.1 (C-1), 49.2 (CHN), 60.7 (CH_2O), 123.1 ($2 \times CH_{arom}$), 131.9 (C_{arom}), 133.8 ($2 \times CH_{arom}$), 168.4 ($2 \times$ C=O), 173.2 (C=O)

[a] Substituent R^2 refers to the precursor **12**.
[b] After chromatography.

with stirring. After 30 min of stirring at 0 °C the yellow Et_2O phase of diazoethane (about 0.5 M) was separated.

c) Cycloaddition

Method A: A 10-fold excess of a freshly prepared solution of CH_2N_2 in Et_2O (about 1 M) was added to a cooled solution (–20 to 0 °C) of **1** (1 mmol) in Et_2O (10 mL). The reaction mixture was allowed to warm up to r.t. overnight. The resulting solution was evaporated (rotary evaporator) and the remaining solid material was recrystallized from Et_2O. Oily products were purified by column chromatography on silica gel (hexane/Et_2O, 1:1). For **1f, 1g,** (*Z*)-**1f** or (*Z*)-**1g** the mixture was kept at r.t. for 7 d. The solid product obtained after evaporation of the solvent was separated by column chromatography on silica gel eluting **4** and **11** with hexane/Et_2O (6:1) and afterwards **3** and **10** with hexane/Et_2O (1: 1) as eluents.

Method B: A freshly prepared ≈0.5 M solution of diazoethane in Et_2O (6 mL, 3 mmol for compound **3c**; 5 mL, 2.5 mmol for **3h**) was added to an ice-cold solution of **1** (150 mg, 0.8 mmol for **1a**; 90 mg, 0.4 mmol for **1d**) in Et_2O (5 mL). The mixture was allowed to warm up to r.t. overnight. The solvent was removed and the remaining product was either recrystallized from Et_2O/pentane (**3c**, solid) or purified by column chromatography on silica gel with hexane/Et_2O (1:1) (**3h**, oil; R_f 0.4).

Method C: A solution of 2 M trimethylsilyldiazomethane in hexane (0.5 mL, 1 mmol, Aldrich) was mixed with a solution of **1a (**100 mg, 0.5 mmol) in benzene (20 mL). The mixture was refluxed till the reaction was complete (TLC monitoring) and the solvent was removed under vacuum. The remaining crude product (dr 83:17) was purified by column chromatography on silica gel (hexane/Et_2O, R_f 0.6) and finally by recrystallization from Et_2O affording **3d** as colourless crystals.

Method D: A mixture of the **1a** (100 mg, 0.5 mmol), 2 M solution of trimethylsilyldiazomethane in hexane (0.5 mL, ≈ 1 mmol) and CH_2Cl_2 (5 mL) was transferred to a Teflon tube. The sealed tube was kept in a high pressure set at 10 kbar at r.t. for 24 h. The resulting mixture was evaporated and purified by column chromatography on silica gel (hexane/Et_2O, 6:1). The resulting colourless oily **3d** crystallized in the refrigerator after some time.

Method E: A solution of **1a** (320 mg, 1.6 mmol) and ethyl diazoacetate (190 mg, 1.9 mmol) in CH_2Cl_2 (5 mL) was placed in a sealed

Teflon tube and kept under 14 kbar at r.t. for 3 d. The resulting mixture was concentrated at 60 °C under vacuum and the yellow oil obtained was purified by filtration on silica gel (hexane/Et_2O, 6:1) (dr 89:11). Final column chromatography on silica gel (hexane/Et_2O, 6:1) afforded the pure diastereomer **6a**.

(3*R*)-(*E*)-2-Benzylidene-3-methyl-β-lactone (8):
A 3 M aq HCl (≈3 mL) solution was added to a solution of **1f** (1.88 g, 7.22 mmol) in THF (20 mL). The mixture was stirred at r.t. until the reaction was complete (TLC). The solution was extracted with Et_2O (5 × 10 mL). The combined Et_2O phases were extracted with satd aq $NaHCO_3$ solution and brine. The organic phase was dried (Na_2SO_4) and evaporated using a rotatory evaporator. The remaining β-hydroxy acid **7** (1.08 g, 78% yield) was dissolved in CH_2Cl_2 (20 mL) without prior purification. Methanesulfonyl chloride (3 mL, 39 mmol) and Na_2CO_3 (3 g) were added at 0 °C under stirring. The mixture was stirred at 0 °C for 1 h and at r.t. for 3 h. After complete reaction (TLC) Na_2CO_3 was filtered off. The organic phase was washed with satd aq $NaHCO_3$ solution (3 × 10 mL) and with brine (10 mL). After drying (Na_2SO_4) the solution was concentrated at r.t. under vacuum. Column chromatography on silica gel (hexane/Et_2O, 2:1) yielded 490 mg (39%) of **8** as colourless crystalline solid: mp 62–63 °C (Et_2O); $[\alpha]_D$ + 26.8 (*c* = 1, $CHCl_3$).
^{1}H NMR ($CDCl_3$): δ = 1.60 (d, *J* = 6.2 Hz, 3 H, CH_3), 5.42 (q, *J* = 6.2 Hz, 1 H, CH), 7.04 (s, 1 H, 1'-H), 7.26–7.39 (m, 5 H, C_6H_5).
^{13}C NMR ($CDCl_3$): δ = 17.8 (CH_3), 76.4 (CH), 129.2, 129.8 (CH_{arom}), 130.0 (CH-1'), 130.6 (CH_{arom}), 132.1 (C-3), 137.2 (C_{arom}), 164.6 (C=O).
IR (KBr): ν = 3426, 1799, 1691, 1450, 1261, 1136, 1116, 808, 771, 691 cm^{-1}.
MS (70 eV): *m*/*z* = 174 (M^+, 100), 159 (69), 131 (54), 129 (48), 115 (54), 103 (59), 102 (58), 77 (37), 51 (32), 43 (18), 39 (18).

Spiro-β-lactone 9:
A freshly prepared 1 M solution of CH_2N_2 in Et_2O (10 mL, 10 mmol) was added to a solution of **8** (110 mg, 0.63 mmol) in Et_2O (10 mL) at 0 °C. The mixture was allowed to warm up to r.t. overnight and the solution was evaporated to dryness. The remaining white solid (134 mg, 98%) was recrystallized from Et_2O.
^{1}H NMR ($CDCl_3$): δ = 0.90 (d, *J* = 6.6 Hz, 3 H, CH_3), 3.63, 4.73 and 5.00 (ABX, J_{AB} = 17.6 Hz, J_{AX} = 1.1 Hz, J_{BX} = 7.6 Hz, 3 H, 1 C*H*-Ph, CH_2-pyrazoline), 5.65 (q, *J* = 6.6 Hz, 1 H, CH), 6.72–7.24 (m, 3 H, C_6H_5).
^{13}C NMR ($CDCl_3$): δ = 17.8 (CH_3), 40.0 (CH), 87.5 (CH_2), 108.5 (C-pyrazoline), 126.9, 127.0, 129.6 (CH_{arom}), 137.9 (C_{arom}), 164.3 (C=O).

Ethyl (*S*)-4-Phenyl-1-pyrazoline-3-carboxylate [(*S*)-5]:
NaOEt (64 mg, 0.93 mmol) was added to a solution of **9** (200 mg, 0.93 mmol) in anhyd EtOH (20 mL). After stirring overnight the solvent was evaporated under vacuum. The resulting mixture was separated by column chromatography on silica gel (EtOAc/hexane, 1:1; R_f 0.5); yield: 73 mg (39%); light yellow oil; $[\alpha]_D$ –26 (*c* = 0.5, $CHCl_3$).
^{1}H NMR ($CDCl_3$): δ = 1.14 (t, *J* = 7.1 Hz, 3 H, CH_3), 3.62 (dd, ^1J = 5.9 Hz, ^2J = 10.0 Hz, 1 H, CH), 4.00 (m, 1 H, CH_2-pyrazoline), 4.09 (q, *J* = 7.1 Hz, 2H, OCH_2), 4.29 (m, 1 H, CH_2-pyrazoline), 6.16 (s, 1 H, NH), 7.16–7.25 (m, 5 H, C_6H_5).
^{13}C NMR ($CDCl_3$): δ = 14.2 (CH_3), 49.3 (CH), 58.1 (CH_2N), 61.0 (CH_2O), 127.3, 128.4, 129.4 (CH_{arom}), 140.8 (C_{arom}), 145.6 (C=N), 162.2 (C=O).

Ethyl (*R*)-4-Phenyl-1-pyrazoline-3-carboxylate [(*R*)-5]:
A mixture of NaOEt (45 mg, 0.66 mmol), pyrazoline **3i** (200 mg, 0.66 mmol) and anhyd EtOH (20 mL) was reacted and worked up as shown for (*S*)-**5** (see above) affording 33 mg (23 %) of (*R*)-**5** as a light yellow oil; $[\alpha]_D$ +20 (*c* = 1, $CHCl_3$). ^{1}H NMR and ^{13}C NMR spectra were identical with the spectra of (*S*)-**5**.

X-Ray Crystal Structure Analysis of Pyrazoline 10b:
Crystal data: $C_{17}H_{22}N_2O_3$, M_r = 302.37, monoclinic, *C*2, *a* = 1993.8(5), *b* = 614.6(2), *c* = 1348.7(3) pm, β = 102.35(2)°, *V* = 1.6144 nm^3, *Z* = 4, D_x = 1.244 Mg m^{-3}, *F*(000) = 648, λ(Mo *Kα*) = 71.073 pm, μ = 0.09 mm^{-1}, *T* = –100 °C.
Data collection and reduction: Irregular colourless prism 1.0 × 0.25 × 0.2 mm, Siemens P4 diffractometer, 2661 intensities to $2\theta_{max}$ 55°, 2002 independent. *Structure solution*: direct methods.
Structure refinement: anisotropic on F^2 (program SHELXL-93, G.M. Sheldrick, University of Göttingen); H atoms with riding model or rigid methyl groups; *wR*(F^2) 0.112 (all refl.), *R*(*F*) 0.046 ($F > 4\sigma(F)$) for 203 parameters and 206 restraints (to light atom *U* components); max. Δρ 315 e nm^{-3}, *S* = 0.98. The absolute configuration was based on the known configuration at C2 and C3. Full details have been deposited at Fachinformationszentrum Karlsruhe, Gesellschaft für wissenschaftlich-technische Information mbH, 76344 Eggenstein-Leopoldshafen and can be obtained by quoting a full literature citation and the deposition number CSD 408033.

Spirocyclopropanes 12 by N_2-Elimination from Pyrazolines 3; General Procedure:
A solution of the spiropyrazoline **3** (0.5 mmol) in degassed benzene (200 mL) was irradiated at 330 nm for 3–12 h (TLC-control). After the reaction was complete, the solvent was removed under vacuum. In most cases products **12** remained as colorless oils in analytically pure form. In some cases further column chromatography was necessary (**12a**: hexane/Et_2O, 7:1; R_f 0.5; **12e**: hexane/Et_2O, 10:1; R_f 0.85) (Table 2).

Cyclopropanecarboxylic Acids 13 (R^4 = H); General Procedure:
A 10% aq HCl solution (5 mL) was added to a solution of **12** (0.5 mmol) in THF (10 mL). After stirring at r.t. overnight Et_2O was added (20 mL). The solution was washed with H_2O (3 × 10 mL). The product was extracted from the organic phase with several portions of satd aq $KHCO_3$ solution. After acidification (pH 1–2) of the aq phase with 10% aq HCl, the product was separated by extraction with Et_2O (3 × 20 mL). The organic phase was dried (Na_2SO_4) and evaporated under vacuum affording the product **13** as a colourless oil (Table 2).

Compound **13c:**
NaOMe (66 mg, 1.2 mmol) was added to a solution of **12a** (220 mg, 0.82 mmol) in anhyd MeOH (20 mL) at 0 °C under stirring. The mixture was allowed to warm up to r.t. and was stirred until the reaction was complete (TLC, about 12 h), poured into satd aq NH_4Cl solution (10 mL) and extracted with CH_2Cl_2 (3 × 30 mL). The dried organic phase (Na_2SO_4) was concentrated under vacuum and the residue was submitted to column chromatography on silica gel (hexane/Et_2O, 6:1) to afford 130 mg (73%) of the product **13c**.

Compound **13d:**
Solid K_2CO_3 (157 mg, 1.13 mmol) was added to a solution of the spirocyclopropane **12e** (234 mg, 1.03 mmol) in anhyd EtOH (20 mL). The mixture was stirred overnight at r.t. After filtering off the K_2CO_3, the filtrate was evaporated to dryness. The residue was dissolved in EtOAc (20 mL) and the organic phase was washed with aq NH_4Cl solution (2 × 10 mL) and with brine (20 mL). The organic phase was dried (Na_2SO_4) and the solvent was stripped off under vacuum affording 140 mg (75 %) **13d** as a colourless oil.

Ethyl 2-Ethyl-(1-phthalimidoethyl)cyclopropanecarboxylate (14):
Ph_3P (100 mg, 0.42 mmol), phthalimide (65 mg, 0.42 mmol) and diethyl azodicarboxylate (72 μL, 0.42 mmol) were added to a solution of **13d** (70 mg, 0.38 mmol) in anhyd THF (10 mL). The resulting reddish brown solution was stirred at r.t. overnight. The solvent was removed under vacuum and the crude product was purified by column chromatography on silica gel (hexane/Et_2O, 1:1; R_f 0.5) affording 60 mg (50 %) **14** as a light yellow oil (Table 2).

5-Alkylidene-1,3-dioxan-4-ones 15; General Procedure:
A solution of spiropyrazoline **3** (0.7 mmol) in xylene (20 mL) was stirred at 130°C for 5 h. The solvent was removed under vacuum and the crude product was purified by column chromatography (hexane/EtOAc, 1:1) affording the corresponding **15** as colourless oils.

We gratefully acknowledge the financial support from the Deutsche Forschungsgemeinschaft (DFG) and the Fonds der Chemischen Industrie. We thank Zeneca Biopolymers for donation of polyhydroxybutyrate and Shell AG for a generous gift of pivalaldehyde.

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