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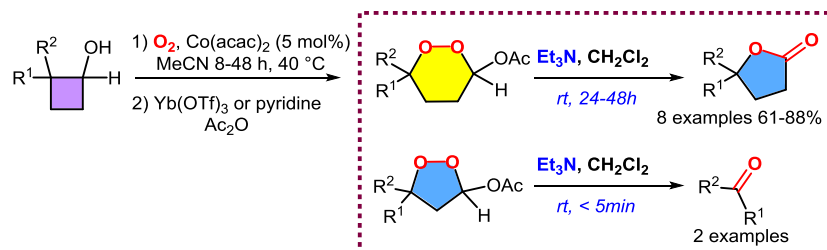
From Ring-Expansion to Ring-Contraction: Synthesis of γ -Lactones from Cyclobutanols and Relative Stability of 5- and 6-membered Endoperoxides Toward Organic Bases.

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Abstract Cyclobutanols undergo a ring expansion with molecular oxygen in the presence of $\text{Co}(\text{acac})_2$ to afford 1,2-dioxane-hemiperoxyketals. In the course of acylation, we observed that endoperoxides rearranged into γ -lactone in the presence of triethylamine. Thus, a generalization of this ring contraction through a Kornblum-DeLaMare rearrangement is here reported. Application of this transformation to monosubstituted 1,2-dioxane derivatives also led to 1,4-ketoaldehydes, in proportions depending on the nature of the substituent. These same conditions applied to 5-membered dioxolane analogs led to fragmentation instead, through a retro-aldol type process. This study emphasizes the difference of stability of 1,2-dioxane and 1,2-dioxolane against organic bases, 1,2-dioxolanes having proved to be particularly reactive whereas 1,2-dioxanes showed a relative tolerance under these conditions.

Key words peroxides, ring contraction, ring-expansion, lactones, fragmentations, rearrangement, heterocycles

Endoperoxides are a class of heterocycles found in several hundred natural products. These compounds exhibit a large spectrum of antiparasitic, antifungal, antiviral or antibacterial, or cytotoxic activities.¹ Most of them are attributed to the reactivity of the peroxide bond.² Indeed, organic peroxides are known to be unstable in certain conditions: they react easily even with a soft reductant, such as $\text{Fe}(\text{II})$ salts to give alkoxy radicals, undergo Hock rearrangement in acidic media or Kornblum-DeLaMare rearrangement on basic conditions.³

One of the most accessible and most popular pathways to 1,2-dioxolanes is the insertion of molecular oxygen into strained cyclopropyl groups under free-radical conditions. Particularly, cyclopropanols readily undergo a ring-extension to produce 1,2-dioxolane-hemiperoxyketals.⁴⁻⁶ Recently, we found out that cyclobutanols **1a-h** could undergo a similar process to give 1,2-dioxan-3-ols **2a-h** in the presence of $\text{Co}(\text{acac})_2$ and molecular

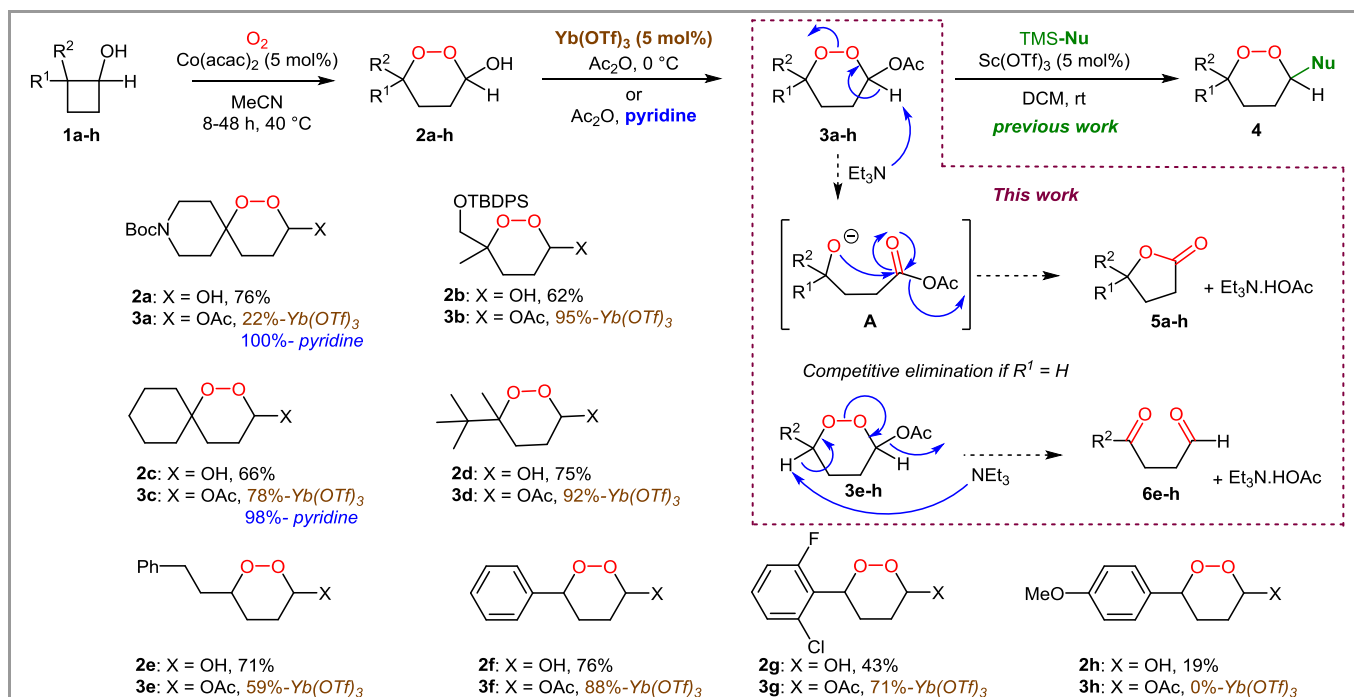
oxygen in acetonitrile, but under slightly more challenging conditions than those used for cyclopropanols (*i.e.*, higher catalyst loading, longer reaction times and higher temperature).⁷ These substrates were then acetylated with Ac_2O in the presence of Lewis acids in overall good yields, excepting **2h**. 1,2-Dioxan-3-yl acetate **3a-fg** were then subjected efficiently to $\text{S}_{\text{N}}1$ alkylations under Scandium(III) triflate catalysis to produce new endoperoxides **4**.^{7,8} (Scheme 1)

Nevertheless, the formation of **3a** was difficult, giving only 22% yield by this method due to the Lewis basicity of carbamate function, which interferes with the Lewis acid catalyst. This unsatisfying result led us to re-explore classical acylation with pyridine on 1,2-dioxane substrates, although it led to decomposition on 1,2-dioxolanes.⁹ To our surprise, it worked admirably for **3a** with a quantitative yield, meaning that 1,2-dioxanes seem far more stable than 1,2-dioxolanes towards organic bases.^t

In our course to acylate **2a** in **3a** in different conditions, we observed that stronger bases such as triethylamine promoted the formation of a new product which corresponded to γ -lactone **5a**, and our aim was then to study and generalize this transformation to other substrates. The formation of the γ -lactone is undoubtedly due to an elimination process of Et_3N (Kornblum-DeLaMare rearrangement) from **3a-h**, as reported before on 1,2,4-trioxanes,¹⁰ which could lead then to ring-opened intermediates **A**, possessing a hydroxyl group on one side and a mixed anhydride on the other side. Both could react simultaneously in an intramolecular fashion to contract into lactones **5a-h**. In the case of substrates where one of the substituents is hydrogen and not an alkyl group, such as **3e-h**, we could probably obtain 1,4-keto-aldehydes **6e-h** as well in a competitive elimination pathway. Indeed, a similar process was studied previously by Snider on 1,2-dioxene derivatives

showing the existence of both pathways.¹¹ The selectivity towards these two reactional routes will be thus briefly studied.

(Scheme 1)



Scheme 1. Formation of 1,2-dioxanyl acetate **3a-g** and subsequent possible transformations: $\text{S}_{\text{N}}1$ alkylation (previous work) and ring contraction (this work).

The experimental conditions to perform ring-contraction of dioxanes **3a-h** were easy to set up and consisted in the treatment of Et_3N in CH_2Cl_2 at rt until 48 h; the results are gathered in Table 1. In cases of 6,6-disubstituted substrates, γ -lactones **5a-d** were obtained as a sole product and isolated in rather good yields (61-88%). In the case of 6-substituted 1,2-dioxanes, the formation of 1,4-ketoaldehydes was also observed in most cases, as hypothesized. Therefore, substrate **3e**, substituted with an alkyl group, formed lactone **5e** predominantly, but **6e** was also isolated (**5e:6e** = 5:1). With phenyl substituent, **5f** and **6f** were isolated as a 1:1 mixture of products. Dioxane **3g**, substituted with an electron-withdrawing group at meta position of aromatic substituent, led exclusively to lactone **5g**.

As the catalyzed acylation of **2h** with $\text{Yb}(\text{OAc})_3$ led to degradation (Scheme 1), the pyridine-mediated protocol was thus applied. While the acylation product **3h** was first observed when the reaction was monitored by TLC, the acylation product was rapidly converted to the rearranged products **5h** and **6h** under these conditions. After 12h, ketoaldehyde **6h** was predominantly observed along **5h** in a 4:1 ratio (Scheme 2). By mimetism, a one-pot protocol was also applied to dioxanol **2b**, using Et_3N and catalytic DMAP. The ring contraction took place in 7 h, via **3b**, leading to **5b** in 71% yield. This protocol could probably be generalized to most of the dioxolanols. (Scheme 2)

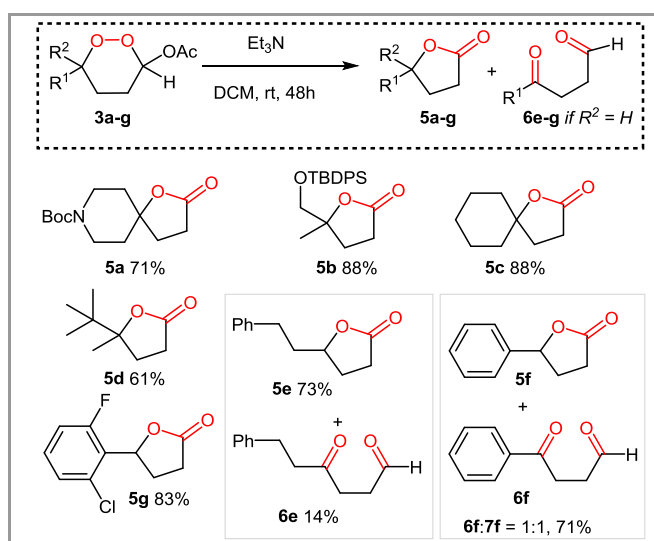
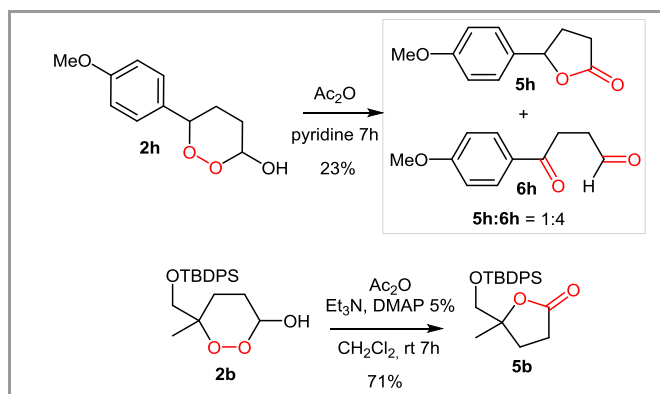


Table 1. Et_3N mediated ring contraction of 1,2-dioxanyl acetates **3a-g**.

In light of these results, we could conclude the effect of the substituents in the selectivity between compounds **5** and **6**. The elimination is predominant at the acetal position, with alkyl groups at position 6. Phenyl substituent facilitates the elimination at position 6 compared to alkyl groups. Electronic effects on aromatic substituents also have a significant role in this selectivity. Thus, electron-withdrawing groups seem to suppress the reactivity at the benzylic position, whereas electron-donating groups do the opposite. These facts are consistent with the general observations of greater ease of oxidation of benzyl alcohols than aliphatic alcohols and even

greater oxidizability of *p*-methoxybenzyl alcohols or their ether derivatives.



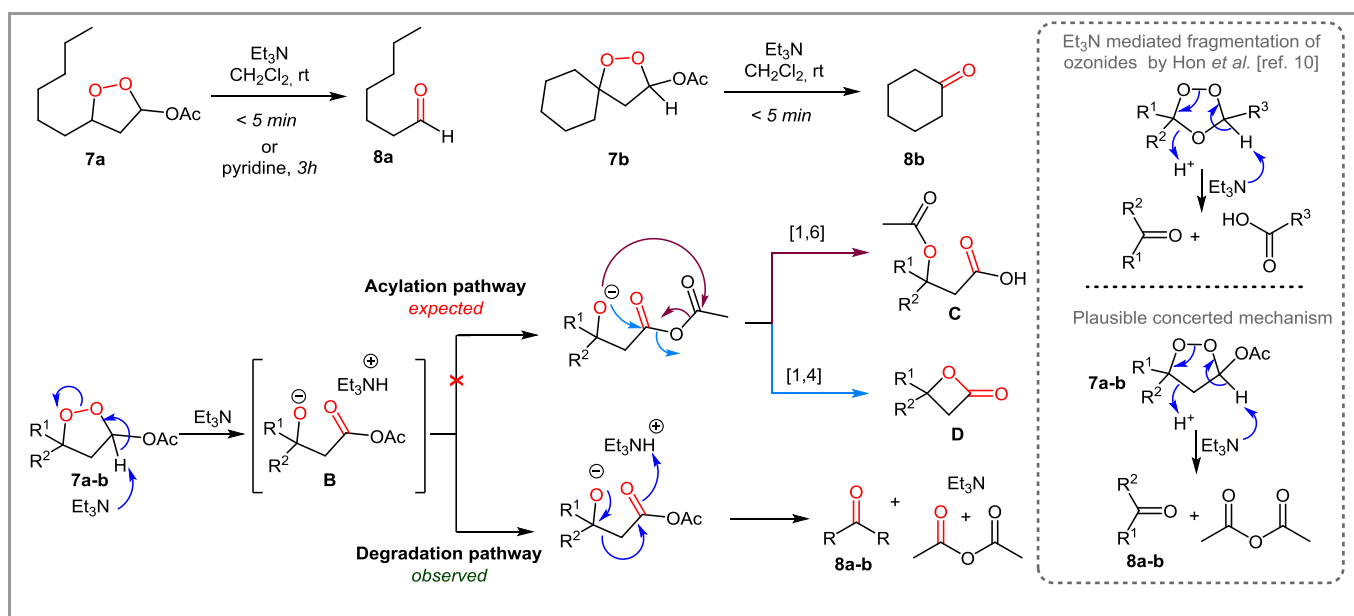
Scheme 2. Direct rearrangement from 1,2-dioxanols **2h** and **2b**

Experimental attempts to transpose this ring contraction process to 1,2-dioxolanyl acetates **7a** and **7b** were driven. Ideally, we desired that β -lactones **D** could be obtained from these 5-membered endoperoxides from 1,4-attack to intermediate mixed anhydride **B**, by similitude with substrates **3a-h**. Nevertheless, a 1,6-attack of the hydroxy group to the acetate residue might also have a chance to be observed due to a more favorable angle of attack, leading to acetates **C**. (Scheme 3)

However, the utilization of Et_3N on 1,2-dioxolanes **7a** and **7b** did not lead to expected products **C** or **D**. Instead, heptanal **8a** and cyclohexanone **8b** were the sole products observed. The degradation process from intermediate **B** could be rationalized by a retro-aldol reaction following the Kornblum-DeLaMare rearrangement. The two processes are eventually concerted, which suppress the existence of intermediate **B** and could

explain that the fragmentation occurs even with pyridine without observing a reprotonation of **B**. A similar transformation was, for example, reported by Hon *et al.* to degrade ozonides with amines in place of a reductant.¹² (Scheme 3) The reaction process leading to **8a-b** was also noticed to be extremely fast; the starting material was consumed in less than 5 min, producing an exotherm. Pyridine was also sufficiently basic to promote this fragmentation, needing three hours to observe complete conversion, whereas most 1,2-dioxanes proved to be inert to this reagent. (Scheme 3)

In summary, after developing a ring expansion of cyclobutanol **1a-h** into 1,2-dioxanes **2a-h** by insertion of oxygen, we further studied the reactivity of 1,2-dioxanes, and by extension 1,2-dioxolanes towards organic bases. Therefore 1,2-dioxanyl acetates **3a-g** could undergo a ring-contraction into γ -lactones **5a-g** by performing a Kornblum-DeLaMare rearrangement with Et_3N . When position 6 of the 1,2-dioxane is monosubstituted, another rearrangement pathway could also occur, leading to 1,4-ketoaldehydes **6e-h**. The nature of the substituent at this position is crucial for the outcome of the selectivity between products **5** and **6**. Considering that we start from cyclobutanols **1a-g**, this transformation is an alternative to Baeyer-Villiger oxidation. The same protocol was applied to 1,2-dioxolanyl acetates **7a-b** but led instantly to a fragmentation of the molecule into heptanal or cyclohexanone. We could establish the generally much higher stability of 1,2-dioxanes than 1,2-dioxolanes under basic conditions (excluding substrates with electron-donating substituents such as **2h** and **3h**), which opens a window to perform faster reactions under basic conditions with this heterocycle. This observation gives rise to a potential explanation for the lower number of isolated natural 5-membered endoperoxides compared to 6-membered ones.



Scheme 3. Fragmentation of 1,2-dioxolanyl acetate **7a** and **7b** by organic base: Synthetic expectations and ring expansion of cyclobutanols into 1,2-dioxanes and further possible transformations.

Experimental Section

CH_2Cl_2 was purified by filtration over activated molecular sieves. MeCN was purchased as HPLC grade and used as received. Analytical thin-layer chromatography (TLC) was performed on silica gel 60 F₂₅₄ (0.25 mm)

plates purchased from Merck. Compounds were visualized by exposure to a UV lamp ($\lambda = 254$ and 365 nm) and/or an acidic solution of vanillin in EtOH followed by gentle heating. Flash chromatographies were performed with Merck (230-400 mesh) silica gel. ^1H and ^{13}C NMR spectra were recorded by using Bruker Avance 300 (300 MHz) spectrometers in the indicated solvent. An optimized sequence for 1D ^{13}C spectra, called UDEFT, was used.¹³ Chemical shifts (δ) are given in ppm and the coupling constants (J) in Hz. The solvent signals were used as reference (CDCl₃: $\delta_{\text{C}} = 77.16$ ppm, residual CHCl₃ in CDCl₃: $\delta_{\text{H}} = 7.26$ ppm). Multiplicities are described by the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, quint = quintet, sext = sextet, sept = septet, m = multiplet, br = broad. Infrared spectra were recorded using a Bruker IRTF Vector 22 spectrometer, and wavenumbers (ν) were given in cm^{-1} . High-resolution mass spectra were obtained on a Waters LCT Premier (ESI-TOF) spectrometer.

CAUTION: Although 1,2-dioxanes seem relatively stable in our hands, peroxides always present an evident risk of explosion, and all precautions must be taken to avoid any hazard. In particular, the concentrations on rotavapor must be conducted with gentle heating, not exceeding 30 °C. Reaction temperatures should be controlled not to exceed 35-40 °C in case of exotherm.

Preparation of 6-(2-chloro-6-fluorophenyl)-1,2-dioxan-3-ol (1g)

To a suspension of 1-bromopropyl-3-triphenylphosphonium bromide (8.82 g, 8.92 mmol, 1.5 equiv) in THF (20 mL) under argon atmosphere was added a solution of *t*-BuOK (4.25 g, 37.83 mmol, 4.2 equiv) in THF (40 mL) via cannula, and the reaction mixture turned to bright orange. The reaction mixture was then heated at reflux with an oil bath for 90 min and 2-chloro-6-fluorobenzaldehyde (2.01 g, 12.61 mmol, 1 equiv) was added. The reflux was continued for 2 h, and the reaction mixture was cooled down to room temperature. The reaction mixture was then poured in a large Erlenmeyer containing a large amount of pentane (130 mL) and the precipitates were filtered. The filtrate was concentrated, and the residue was purified on a silica gel chromatography with pure petroleum ether to give (cyclopropylidene)methyl-2-chloro-6-fluorobenzene (1.368 g, 59%) as a light yellow oil.

IR (cm^{-1}): 1600, 1570, 1460, 1448, 1246, 983, 894, 771.

^1H NMR (300 MHz, CDCl₃) δ 7.19 (dt, $J = 8.0, 1.0$ Hz, 1H), 7.11 (td, $J = 8.1, 5.6$ Hz, 1H), 6.99 (ddd, $J = 10.1, 8.1, 1.2$ Hz, 1H), 6.89 (quint, $J = 2.1$ Hz, 1H), 1.37 – 1.28 (m, 4H).

^{13}C NMR (75 MHz, CDCl₃) δ 160.9 (d, $J = 251.7$ Hz), 133.1 (d, $J = 5.3$ Hz), 128.8 (d, $J = 61.4$ Hz), 127.9 (d, $J = 9.6$ Hz), 125.3 (d, $J = 3.5$ Hz), 124.8 (d, $J = 16.7$ Hz), 114.6 (d, $J = 23.4$ Hz), 110.3, 6.0 (d, $J = 7.8$ Hz), 3.9.

MS (EI) m/z : 182 (M^+ , 3), 154 ($\text{M}^+ - \text{CH}_2 = \text{CH}_2$, 11), 147 ($\text{M}^+ - \text{Cl}$, 100).

To a solution of (cyclopropylidene)methyl-2-chloro-6-fluorobenzene (1.357 g, 7.43 mmol, 1 equiv) in CH₂Cl₂ (15 mL) at 0 °C was added *m*-CPBA (2.014 g, 8.17 mmol, 70-77% in water, 1.1 equiv) in 5 portions over 15 min. After 30 min stirring and disappearance of starting material via TLC monitoring, camphor sulfonic acid was added (86 mg, 0.372 mmol, 0.05 equiv) to ensure total conversion of intermediate epoxides into cyclobutanone, and the reaction mixture was stirred for another 30 min. The reaction mixture was quenched with a 10 % Na₂SO₃ solution (15 mL) and 2% KI solution (4 mL). The mixture was stirred vigorously for 20 minutes and extracted with Et₂O three times (50 mL in total). The combined organic layers were washed three times with a saturated NaHCO₃ solution (150 mL), dried over MgSO₄, filtered, and concentrated on a rotavapor. The residue was then purified on a silica gel chromatography (Petroleum ether: Ether, 95:5) to give 2-(2-chloro-6-fluorophenyl)cyclobutan-1-one (1.156 g, 78%) as a light yellow oil.

IR (cm^{-1}): 1788, 1604, 1573, 1452, 1247, 1188, 1074, 873, 783.

^1H NMR (300 MHz, CDCl₃) δ 7.17 (td, $J = 3.9, 2.7$ Hz, 2H), 6.98 (ddd, $J = 9.6, 6.1, 3.4$ Hz, 1H), 4.91 (dd, $J = 10.8, 8.4$ Hz, 1H), 3.25 (dd, $J = 8.8, 7.6$ Hz, 2H), 2.50 (tdd, $J = 10.8, 8.2, 7.0$ Hz, 1H), 2.34 (ttd, $J = 10.8, 8.8, 1.5$ Hz, 1H).

^{13}C NMR (75 MHz, CDCl₃) δ 206.0, 161.9 (d, $J = 249.2$ Hz), 129.3, 129.3 (d, $J = 10.0$ Hz), 125.6 (d, $J = 3.5$ Hz), 124.0 (d, $J = 17.7$ Hz), 114.5 (d, $J = 22.7$ Hz), 57.4, 45.5, 17.9.

HRMS (ESI) m/z : calcd for $[\text{M} + \text{H}]^+$: C₁₀H₈ClFO 199.0320; Found 199.0319.

To a solution of 2-(2-chloro-6-fluorophenyl)cyclobutan-1-one (1.127 g, 5.67 mmol) in MeOH (18 mL) at 0 °C was added NaBH₄ (215 mg, 5.67 mmol, 1 equiv) in 3 portions over 10 min. The reaction mixture was then allowed to stir at rt for 1 h, and the reaction mixture was then quenched with saturated NH₄Cl (18 mL). The reaction mixture was extracted with a 50:50 Et₂O:petroleum ether mixture thrice (40 mL x3) and the combined organic layers were washed twice with brine (30 mL x2). The ethereal phase was then dried over MgSO₄, filtered, and concentrated under vacuum to yield 2-(2-chloro-6-fluorophenyl)cyclobutan-1-ol **2g** as a 12:1 *cis:trans* mixture of diastereomers (927 mg, 81%) as a light yellow oil. The compound was used in the next step without further purification.

IR (cm^{-1}): 3390, 1602, 1573, 1456, 1242, 1101, 877, 779.

^1H NMR (300 MHz, CDCl₃, major diastereomer) δ 7.18 (dd, $J = 8.2, 1.7$ Hz, 1H), 7.11 (dd, $J = 8.0, 5.4$ Hz, 1H), 6.98 (ddd, $J = 11.3, 7.8, 1.8$ Hz, 1H), 4.87 – 4.74 (m, 1H), 4.07 (d, $J = 7.8$ Hz, 1H), 2.91 – 2.76 (m, 1H), 2.51 – 2.27 (m, 2H), 2.08 (d, $J = 17.7$ Hz, 1H), 1.80 (dd, $J = 5.8, 2.2$ Hz, 1H).

^{13}C NMR (75 MHz, CDCl₃, major diastereomer) δ 163.18 (d, $J = 248.0$ Hz), 135.5 (d, $J = 8.5$ Hz), 128.14 (d, $J = 10.1$ Hz), 125.76 (d, $J = 3.3$ Hz), 125.55 (d, $J = 16.4$ Hz), 115.07 (d, $J = 24.8$ Hz), 71.93, 42.53, 30.25 (d, $J = 3.2$ Hz), 22.97 (d, $J = 9.0$ Hz).

HRMS (ESI) m/z : calcd for $[\text{M} - \text{H}_2\text{O} + \text{H}]^+$: C₁₀H₉ClF 183.0371; Found 183.0369.

Preparation of 6-(4-methoxyphenyl)-1,2-dioxan-3-ol (1h)

To a suspension of 1-bromopropyl-3-triphenylphosphonium bromide (10.27 g, 22.04 mmol, 1.5 equiv) in THF (25 mL) under argon atmosphere was added a solution of *t*-BuOK (4.95 g, 44.1 mmol, 3 equiv) in THF (40 mL) via cannula, and the reaction mixture turned to bright orange. The reaction mixture was then heated at reflux with an oil bath for 90 min, and 4-methoxy-benzaldehyde (2.0 g, 14.69 mmol, 1 equiv) was added. The reflux was continued for 2 h, and the reaction mixture was cooled down to room temperature. The reaction mixture was then poured in a large Erlenmeyer containing a large amount of pentane (150 mL), and the precipitates were filtered. The filtrate was concentrated, and the residue was purified on a silica gel chromatography with toluene:petroleum ether (30:70) to give (cyclopropylidene)methyl-4-methoxybenzene (2.27 g, 97%) as a light yellow oil.

IR (cm^{-1}): 1608, 1510, 1435, 1290, 1244, 1172, 1033, 839, 744, 696.

^1H NMR (300 MHz, CDCl₃) δ 7.47 (d, $J = 8.7$ Hz, 2H), 6.88 (d, $J = 8.7$ Hz, 2H), 6.70 (p, $J = 1.9$ Hz, 1H), 3.82 (s, 3H), 1.39 (ddd, $J = 9.5, 5.6, 1.9$ Hz, 2H), 1.16 (ddd, $J = 9.5, 5.5, 1.9$ Hz, 2H).

^{13}C NMR (75 MHz, CDCl₃) δ 158.75, 131.44, 127.84, 121.82, 117.78, 114.10, 55.44, 4.15, 0.65.

MS (EI) m/z : 160 (M^+ , 84), 159 ($\text{M}^+ - \text{H}$, 100), 145 ($\text{M}^+ - \text{Me}$, 74), 129 ($\text{M}^+ - \text{OMe}$, 77).

To a solution of (cyclopropylidene)methyl-4-methoxybenzene (2.2767 g, 14.21 mmol, 1 equiv) in CH₂Cl₂ (30 mL) at 0 °C was added *m*-CPBA (3.503 g, 14.21 mmol, 70-77% in water, 1.0 equiv) in 5 portions over 15 min. After 30 min stirring and disappearance of starting material via TLC monitoring, camphor sulfonic acid was added (164 mg, 0.71 mmol, 0.05 equiv) to ensure total conversion of intermediate epoxides into cyclobutanone, and the reaction mixture was stirred for another 30 min. The reaction mixture was quenched with a 10 % Na₂SO₃ solution (30 mL) and 2% KI solution (8 mL). The mixture was stirred vigorously for 20 minutes and extracted with Et₂O three times (100 mL in total). The combined organic layers were washed three times with a saturated NaHCO₃ solution (150 mL in total), dried over MgSO₄, filtered, and concentrated on a rotavapor. The residue was then purified on a silica gel chromatography (Petroleum ether: Ether, 95:5) to give 2-(4-methoxyphenyl)cyclobutan-1-one (1.156 g, 78%) as a light yellow oil.

IR (cm⁻¹): 1788, 1604, 1573, 1452, 1247, 1188, 1074, 873, 783.

¹H NMR (300 MHz, CDCl₃) δ 7.16 (d, *J* = 8.7 Hz, 2H), 6.87 (d, *J* = 8.7 Hz, 2H), 4.47 (ddt, *J* = 10.7, 8.2, 2.6 Hz, 1H), 3.79 (s, 3H), 3.21 (dddd, *J* = 17.6, 10.5, 8.3, 2.4 Hz, 1H), 3.01 (dddd, *J* = 17.6, 9.7, 5.0, 2.6 Hz, 1H), 2.52 (dtd, *J* = 11.0, 10.5, 5.0 Hz, 1H), 2.17 (ddt, *J* = 11.1, 9.7, 8.2 Hz, 1H).

¹³C NMR (75 MHz, CDCl₃) δ 208.33, 158.80, 128.94, 128.20, 114.27, 64.13, 55.44, 44.87, 18.20.

MS (EI) *m/z*: 176 (M⁺, 4), 134 (M⁺-O=C=CH₂, 100).

To a solution of 2-(4-methoxyphenyl)cyclobutan-1-one (1.500 g, 8.51 mmol) in MeOH (30 mL) at 0 °C was added NaBH₄ (322 mg, 8.51 mmol, 1 equiv) in 3 portions over 10 min. The reaction mixture was then allowed to stir at rt for 1 h, and the reaction mixture was then quenched with saturated NH₄Cl (25 mL). The reaction mixture was extracted with a 50:50 Et₂O:Petroleum ether mixture thrice (50 mL x3) and the combined organic layers were washed twice with brine (40 mL x2). The ethereal phase was then dried over MgSO₄, filtered, and concentrated under vacuum to yield 2-(4-methoxyphenyl)cyclobutan-1-ol as a 35:65 *cis:trans* mixture of diastereomers (1.518 g, quantitative) as a light yellow oil. The compound was used in the next step without further purification.

IR (cm⁻¹): 3336, 1610, 1510, 1462, 1244, 1176, 1105, 1064, 1035, 827.

¹H NMR (300 MHz, CDCl₃, 35:65 mixture of diastereomers) δ 7.23 (d, *J* = 8.6 Hz, 0.70H), 7.16 (d, *J* = 8.6 Hz, 1.40H), 6.92 (d, *J* = 8.6 Hz, 0.70H), 6.86 (d, *J* = 8.6 Hz, 1.40H), 4.47 (p, *J* = 6.0 Hz, 0.35H), 4.11 (q, *J* = 8.1 Hz, 1H), 3.81 (s, 1.05H), 3.79 (s, 1.95H), 3.79 – 3.61 (m, 0.35H), 3.19 (q, *J* = 9.0 Hz, 0.65H), 2.50 – 2.34 (m, 0.35H), 2.32 – 2.20 (m, 1H), 2.19 – 2.02 (m, 1H+0.65H(OH)), 2.01 – 1.92 (m, 0.35H), 1.83 (tdd, *J* = 10.5, 9.3, 8.4 Hz, 0.65H), 1.55 (qd, *J* = 10.4, 7.9 Hz, 0.65H), 1.40 (d, *J* = 7.2 Hz, 0.35H, OH).

¹³C NMR (75 MHz, CDCl₃, 35:65 mixture of diastereomers) δ 158.62, 158.35*, 135.17*, 130.32, 129.59, 127.71*, 114.25, 113.96*, 73.95*, 69.44, 55.43 (both diastereomers), 51.26*, 46.29, 31.01, 29.65*, 20.43, 19.01*. (* = major diastereomer)

HRMS (ESI) *m/z*: calcd for [M-H₂O+H]⁺: C₁₁H₁₃O 161.0961; Found 161.0960; calcd for [M+NH₄]⁺: C₁₁H₁₈NO₂ 196.1332, found 196.1327.

Preparation of 1,2-dioxanyl-3-ol 2a-f. General Procedure A To a solution of cyclobutanols **1a-h** (1 equiv) in MeCN (10 mL/mmol of substrate) was added Co(acac)₂ (0.05 equiv). The brownish reaction mixture was then lightly bubbled with O₂ for 5 min, and the oxygen atmosphere was maintained with a balloon in rubber. The reaction mixture was then heated to 40 °C with an oil bath, and once the reaction mixture was in contact with pure O₂, the color turned slowly to intense green, a characteristic of Co(III) salts. The reaction was monitored by TLC, and after most of starting material was consumed (c.a. 8 to 48 h of reaction), the reaction mixture was concentrated on a rotavapor under vacuum with gentle heating (no more than 30 °C). The green residue was triturated with ether and was filtered on a small pad of silica gel, washing with Et₂O to remove most of the Cobalt salts. The filtrate was concentrated again, and further purification was accomplished on silica gel column chromatography.

Preparation of compounds 2a-f was already reported by us in a previous study.⁷

6-(2-chloro-6-fluorophenyl)-1,2-dioxan-3-ol (2g)

From 2-(2-chloro-6-fluorophenyl)cyclobutan-1-ol **1g** (915 mg, 4.56 mmol) using the General Procedure A, 6-(2-chloro-6-fluorophenyl)-1,2-dioxan-3-ol **2g** was obtained (458 mg, 43%) in a 65:35 mixture of diastereomers, as a colorless oil. Chromatography eluent: Petroleum Ether/AcOEt 90/10.

IR (cm⁻¹): 3418, 2932, 1607, 1574, 1452, 1248, 1112, 1018, 966, 885, 783.

¹H NMR (300 MHz, CDCl₃) δ 7.26 – 7.15 (m, 2H), 7.05 – 6.93 (m, 1H), 5.77 (ddd, *J* = 12.0, 2.4, 0.8 Hz, 0.65H), 5.66 (ddd, *J* = 12.0, 2.8, 1.0 Hz, 0.35H),

5.49 (ddd, *J* = 9.5, 5.9, 2.3 Hz, 0.35H), 5.40 (ddd, *J* = 7.1, 3.6, 1.6 Hz, 0.65H), 3.51 (d, *J* = 7.1 Hz, 0.65H, OH), 3.38 (d, *J* = 5.9 Hz, 0.35H, OH), 2.69 (dtdd, *J* = 13.6, 12.0, 5.5, 1.3 Hz, 0.65H), 2.51 (tddd, *J* = 13.5, 12.0, 4.6, 1.2 Hz, 0.35H), 2.21 (ddt, *J* = 13.1, 4.7, 2.2 Hz, 0.35H), 2.12 (m, 0.65H), 2.05 (m, 0.65H), 2.01 (m, 0.35H), 1.82 (dddd, *J* = 13.1, 9.3, 4.8, 1.2 Hz, 0.35H), 1.74 (ddt, *J* = 13.8, 5.4, 2.6 Hz, 0.65H).

¹³C NMR (75 MHz, CDCl₃) δ 130.69* (d, *J* = 10.4 Hz), 130.52 (d, *J* = 10.4 Hz), 126.11* (d, *J* = 3.6 Hz), 126.06 (d, *J* = 3.6 Hz), 115.57* (d, *J* = 2.9 Hz), 115.26 (d, *J* = 2.9 Hz), 98.31, 95.82, 78.92, 78.84*, 30.96, 28.28*, 27.53 (d, *J* = 3.1 Hz), 21.90* (d, *J* = 3.1 Hz). (* = major diastereomer)

HRMS (ESI) *m/z*: calcd for C₁₀H₁₀ClFO₃Na[M+Na]⁺: 255.0195; Found 255.0194.

6-(4-methoxyphenyl)-1,2-dioxan-3-ol (2h)

From 2-(4-methoxyphenyl)cyclobutan-1-ol **1h** (1.52 g, 8.51 mmol) using the general procedure A, 6-(4-methoxyphenyl)-1,2-dioxan-3-ol **2h** was obtained (0.28 g, 16%) in a 65:35 mixture of diastereomers, as white crystals. Chromatography eluent: Petroleum Ether/Et₂O/DCM 70/30/30.

Mp: 123 °C (fusion-decomposition).

IR (cm⁻¹): 3356, 2935, 1612, 1516, 1377, 1292, 1253, 1178, 1143, 1120, 1049, 1028, 997, 970, 823.

¹H NMR (300 MHz, CDCl₃, 65:35 mixture of diastereomers) δ 7.32 (d, *J* = 8.6 Hz, 0.65H), 7.30 (d, *J* = 8.8 Hz, 0.35H), 6.89 (d, *J* = 8.7 Hz, 0.65H), 6.89 (d, *J* = 8.7 Hz, 0.35H), 5.41 (dt, *J* = 4.9, 2.4 Hz, 0.65H), 5.38 (ddd, *J* = 8.9, 6.0, 2.5 Hz, 0.35H), 5.09 (dd, *J* = 11.3, 2.3 Hz, 0.65H), 5.03 (dd, *J* = 9.8, 3.6 Hz, 0.35H), 3.80 (s, 3H), 3.27 (dd, *J* = 6.0, 1.4 Hz, 0.35H, OH), 3.20 (dt, *J* = 5.0, 1.1 Hz, 0.65H, OH), 2.34 (dtd, *J* = 13.3, 11.2, 6.3 Hz, 0.65H), 2.22 – 2.00 (m, 2.35H), 1.81 (ddt, *J* = 13.5, 4.7, 3.3, 2.5 Hz, 0.67H), 1.76 – 1.67 (m, 0.35H).

¹³C NMR (75 MHz, CDCl₃) δ 160.2*, 160.0, 130.5*, 129.95, 129.0*, 128.7, 114.1 (both diastereomers), 98.1, 95.5*, 82.9*, 82.5, 55.4 (both diastereomers), 30.4, 29.5, 28.3*, 24.1*.

HRMS (ESI) *m/z*: calcd for C₁₁H₁₄O₄Na [M+Na]⁺: 233.0784; Found 233.0786.

Acetylation of 1,2-dioxan-3-ol and 1,2-dioxolan-3-ol by Lewis acid catalysis. General Procedure B

To a reaction flask containing 1,2-dioxan-3-ol **2a-h** or 1,2-dioxolan-3-ol **8a-b**, was added Ac₂O (2 mL/mmol of substrate) at 0 °C and Yb(OTf)₃ hydrate was then added (0.05 equiv). After 1 h at 0 °C, the reaction mixture was quenched, poured in an Erlenmeyer containing a saturated NaHCO₃ solution (20 mL/mmol of the substrate) and Et₂O (4 mL/mmol). The reaction mixture was stirred vigorously for 30 min at rt, and the aqueous layer was extracted 3 times with Et₂O (about 20 mL/mmol of the substrate). The combined organic phases were washed with saturated NaHCO₃ twice (about 20 mL/mmol of the substrate), washed with brine once (about 20 mL/mmol of the substrate), dried over MgSO₄, filtered, and concentrated on a rotavapor under vacuum with a gentle heating (no more than 30 °C). The residue was then purified on a silica gel column chromatography.

Acetylation of 1,2-dioxan-yl-3-ols mediated by pyridine. General Procedure C

To a solution of 1,2-dioxan-3-ol **2a-h** in CH₂Cl₂ (0.5 mL/mmol), was added Ac₂O (5 equiv) and pyridine (5 equiv). The reaction mixture was stirred for 2 h at rt and was quenched with ice (≈2 g/mmol). After stirring the mixture for 10 min, Et₂O was added (1 mL/mmol), and the two layers were partitioned. The aqueous layer was extracted thrice with Et₂O (about 10 mL/mmol of the substrate), and the combined organic phases were washed with 10% CuSO₄ solution twice (about 10 mL/mmol of the substrate), saturated NaHCO₃ twice (about 10 mL/mmol of the substrate), washed with brine once (about 20 mL/mmol of the substrate), dried over MgSO₄, filtered, and concentrated on a rotavapor under vacuum with a gentle heating (no more than 30 °C). The residue was then purified on a silica gel column chromatography

Preparation of compounds **3a-f** was already reported by us in a previous study.⁷

N-Boc-3-acetoxy-1,2-dioxo-9-azaspiro[5.5]undecane (3a)

From *N*-Boc-3-hydroxy-1,2-dioxo-9-azaspiro[5.5]undecane **2a** (899 mg, 2.85 mmol) using general procedure C, *N*-Boc-3-acetoxy-1,2-dioxo-9-azaspiro[5.5]undecane **3a** was obtained as a colorless oil (906 mg, 100%). Chromatography eluent: Petroleum Ether/AcOEt 75/25. Characterization data were in agreement with our previous report.⁷

1,2-Dioxaspiro[5.5]undecan-3-yl acetate (3c)

From 1,2-dioxaspiro[5.5]undecan-3-ol **2c** (6.98 g, 40.6 mmol) using general procedure C, 6-phenyl-1,2-dioxan-3-yl acetate **3c** was obtained as a colorless oil (8.5 g, 98%). Chromatography eluent: Petroleum Ether/Et₂O 90/10. Characterization data were in agreement with our previous report.⁷

6-(2-chloro-6-fluorophenyl)-1,2-dioxan-3-yl acetate (3g)

From 6-(2-chloro-6-fluorophenyl)-1,2-dioxan-3-ol **2g** (282 mg, 1.21 mmol) using general procedure B, 6-(2-chloro-6-fluorophenyl)-1,2-dioxan-3-yl acetate **3g** was obtained as a single *cis* diastereomer and a colorless oil (237 mg, 71%). Chromatography eluent: Petroleum/Et₂O 85/15.

¹H NMR (300 MHz, CDCl₃) δ 7.2 – 7.17 (m, 2H), 6.99 (ddd, *J* = 10.5, 7.6, 2.0 Hz, 1H), 6.34 (dd, *J* = 4.0, 1.9 Hz, 1H), 5.80 (ddd, *J* = 11.4, 2.7, 1.2 Hz, 1H), 2.71 (dtdd, *J* = 13.8, 12.2, 4.9, 1.0 Hz, 1H), 2.28 – 1.99 (m, 2H), 2.19 (s, 3H), 1.79 (ddt, *J* = 13.4, 5.5, 2.7 Hz, 1H).

¹³C NMR (75 MHz, CDCl₃) δ 169.77, 162.12 (d, *J* = 254.1 Hz), 135.04 (d, *J* = 6.4 Hz), 130.77 (d, *J* = 9.9 Hz), 126.08 (d, *J* = 3.5 Hz), 123.78 (d, *J* = 15.8 Hz), 115.43 (d, *J* = 23.3 Hz), 93.56, 78.71, 26.44, 22.21 (d, *J* = 4.1 Hz), 21.23.

HRMS (ESI) *m/z*: calcd for C₁₂H₁₂ClFO₄Na [M+Na]⁺ : 297.0300; Found 297.0301.

Preparation of γ-lactones 5a-g and 1,4-ketoaldehyde 6e-g. General Procedure D

To a solution of 1,2-dioxan-3-yl acetate **3a-g** (1 equiv) in CH₂Cl₂ (5 mL/mmol) was added Et₃N (equiv) and the reaction mixture was stirred 48 h at rt. The reaction mixture was quenched with saturated NH₄Cl and was extracted with Et₂O. The organic layer was then dried over MgSO₄, filtered, and concentrated. The residue was then purified on silica gel chromatography.

N-Boc-1-oxa-8-azaspiro[4.5]decane-2-one (5a)

From *N*-Boc-3-acetoxy-1,2-dioxo-9-azaspiro[5.5]undecane **3a** (488 mg, 1.55 mmol) using general procedure D, *N*-Boc-1-oxa-8-azaspiro[4.5]decane-2-one **5a** was obtained as a white solid (281 mg, 71%) without a purification on a silica gel column chromatography.

Mp: 130 °C.

IR (cm⁻¹): 2976, 1769, 1686, 1419, 1365, 1277, 1217, 1159, 1138, 1051, 1010, 964, 945.

¹H NMR (300 MHz, Chloroform-*d*) δ 3.74 (brd, *J* = 13.6 Hz, 2H), 3.18 (brt, *J* = 10.8 Hz, 2H), 2.56 (t, *J* = 8.4 Hz, 2H), 1.99 (t, *J* = 8.4 Hz, 2H), 1.75 (brd, *J* = 13.6 Hz, 2H), 1.61 (ddd, *J* = 13.3, 10.8, 4.5, 2H), 1.39 (s, 9H).

¹³C NMR (75 MHz, CDCl₃) δ 176.1, 154.5, 83.7, 79.8, 40.3(br), 36.3, 33.0, 28.4, 28.2.

HRMS (ESI) *m/z*: calcd for [M+Na]⁺ C₁₃H₂₁NO₄Na 278.1363; Found 278.1364.

5-(tert-butylidiphenylsiloxy)methyl-5-methyldihydrofuran-2(3H)-one (5b)

-From **3b** using general procedure D: (864 mg, 2.01 mmol) 5-(tert-butylidiphenylsiloxy)methyl-5-methyldihydrofuran-2(3H)-one **5b** was obtained as a colorless oil (652 mg, 88%). Chromatography eluent: Petroleum Ether/AcOEt 85/15.

-From **2b** using the following one-pot procedure: To a solution of **2b** (295 mg, 0.76 mmol) in CH₂Cl₂ (3 mL), Ac₂O (0.2 ml), Et₃N (0.6 mL), and DMAP (5 mg, 0.04 mmol) were added. The reaction mixture was stirred at rt overnight and then poured into a saturated NaHCO₃ solution. The reaction mixture was then extracted with Et₂O three times, and the combined organic layers were dried over MgSO₄, concentrated, and the residue was purified by silica gel column chromatography with an 85:15 mixture of petroleum ether:AcOEt. **5b** was obtained as a colorless oil (199 mg, 71%).

IR (cm⁻¹): 2932, 2857, 1774, 1427, 1234, 1155, 1112, 945, 823, 742, 702.

¹H NMR (300 MHz, Chloroform-*d*) δ 7.69 – 7.63 (m, 4H), 7.47 – 7.36 (m, 6H), 3.69 (d, *J* = 10.7 Hz, 1H), 3.51 (d, *J* = 10.7 Hz, 1H), 2.77 (ddd, *J* = 17.8, 10.4, 8.5 Hz, 1H), 2.58 (ddd, *J* = 17.8, 10.5, 4.7 Hz, 1H), 2.39 (ddd, *J* = 12.8, 10.5, 4.7 Hz, 1H), 1.95 (ddd, *J* = 12.8, 10.5, 8.5 Hz, 1H), 1.34 (s, 3H), 1.06 (s, 9H).

¹³C NMR (75 MHz, CDCl₃) δ 177.3, 135.8, 135.7, 133.1, 132.6, 130.0, 128.0, 86.3, 69.9, 30.5, 30.1, 26.9, 23.7, 19.3.

HRMS (ESI) *m/z*: calcd for [M+Na]⁺ C₂₂H₂₈O₃SiNa 391.1700; Found 391.1701. Calcd for [M+H]⁺ C₂₂H₂₉O₃Si 369.1880; Found 369.1879.

1-oxaspiro[4.5]decane-2-one (5c)

From **3c** (212 mg, 1.00 mmol) using general procedure D, 1-oxaspiro[4.5]decane-2-one **5c** was obtained as a colorless oil (172.2 mg, 88%). Chromatography eluent: Petroleum Ether/Et₂O 85/15.¹⁴

IR (cm⁻¹): 2933, 1764, 1420, 1220, 1191, 1149n 1126, 1047, 956, 904

¹H NMR (300 MHz, Chloroform-*d*) δ 2.60 (t, *J* = 8.3 Hz, 2H), 2.02 (t, *J* = 8.3 Hz, 2H), 1.88 – 1.66 (m, 4H), 1.65 – 1.47 (m, 5H), 1.47 – 1.35 (m, 1H).

¹³C NMR (75 MHz, CDCl₃) δ 177.0, 86.5, 37.1, 33.0, 28.7, 25.1, 22.7.

HRMS (ESI) *m/z*: calcd for C₉H₁₄O₂ [M+H]⁺: 155.1067; Found 155.1065.

5-(tert-butyl)-5-methyldihydrofuran-2(3H)-one (5d)

From **3d** (260 mg, 1.20 mmol) using general procedure D, 5-(tert-butyl)-5-methyldihydrofuran-2(3H)-one **5d** was obtained as a colorless oil (114 mg, 61%). Chromatography eluent: Petroleum Ether/Et₂O 90/10.

IR (cm⁻¹): 2974, 1762, 1379, 1269, 1198, 1139, 1111, 1083, 966, 939.

¹H NMR (300 MHz, Chloroform-*d*) δ 2.65 (ddd, *J* = 18.1, 10.4, 9.1 Hz, 1H), 2.51 (ddd, *J* = 18.1, 10.2, 4.3 Hz, 1H), 2.28 (ddd, *J* = 13.0, 10.2, 9.1 Hz, 1H), 1.78 (ddd, *J* = 13.1, 10.4, 4.3 Hz, 1H), 1.34 (s, 3H), 0.96 (s, 9H).

¹³C NMR (75 MHz, CDCl₃) δ 177.1, 91.5, 37.4, 29.5, 29.0, 24.9, 22.4.

HRMS (ESI) *m/z*: calcd for C₉H₁₆O₂ [M+H]⁺: 157.1223; Found 157.1227. calcd for C₉H₁₆O₂Na [M+Na]⁺: 179.1043; Found 179.1044.

5-phenethyldihydrofuran-2(3H)-one (5e) and 4-oxo-6-phenylhexanal (6e)

From **3e** (122 mg, 0.49 mmol) using general procedure D, 1-oxaspiro[4.5]decane-2-one **5e** was obtained as a colorless oil (68 mg, 73%), and with 4-oxo-6-phenylhexanal **6e** as a colorless oil (11 mg, 12%). Chromatography eluent: Petroleum Ether/AcOEt 85/15.

5-phenethyldihydrofuran-2(3H)-one 5e¹⁵

IR (cm⁻¹): 2943, 1765, 1454, 1175, 1138, 1031, 918, 750, 700

¹H NMR (300 MHz, Chloroform-*d*) δ 7.37 – 7.27 (m, 2H), 7.27 – 7.14 (m, 3H), 4.52 (tdd, *J* = 8.0, 6.5, 4.8 Hz, 1H), 2.85 (ddd, *J* = 13.9, 9.2, 5.7 Hz, 1H), 2.75 (dt, *J* = 13.9, 8.6, 7.3 Hz, 1H), 2.58 (d, *J* = 6.1 Hz, 1H), 2.55 (dd, *J* = 7.6, 1.5 Hz, 1H), 2.32 (dq, *J* = 13.8, 6.5 Hz, 1H), 2.07 (dtd, *J* = 14.2, 8.5, 5.7 Hz, 1H), 2.00 – 1.83 (m, 2H).

^{13}C NMR (75 MHz, CDCl_3) δ 177.1, 140.8, 128.6, 128.5, 126.3, 80.0, 37.4, 31.7, 28.9, 28.0.

HRMS (ESI) m/z : calcd for $[\text{M}+\text{Na}]^+$ $\text{C}_{12}\text{H}_{14}\text{O}_2\text{Na}$ 213.0886; Found 213.0884. calcd for $[\text{M}+\text{H}]^+$ $\text{C}_{12}\text{H}_{15}\text{O}_2$ 191.1067; Found 191.1067

4-oxo-6-phenylhexanal **6e**¹⁶

IR (cm^{-1}): 2922, 1707, 1375, 1180, 1095, 750, 700.

^1H NMR (300 MHz, Chloroform- d) δ 9.81 (t, J = 0.8 Hz, 1H), 7.32 – 7.24 (m, 2H), 7.19 (t, J = 7.1 Hz, 3H), 2.92 (t, J = 7.4 Hz, 2H), 2.81 – 2.63 (m, 6H).

^{13}C NMR (75 MHz, CDCl_3) δ 207.9, 200.5, 141.0, 128.7, 128.4, 126.3, 44.3, 37.6, 35.0, 29.9.

HRMS (ESI) m/z : calcd for $[\text{M}+\text{H}]^+$ $\text{C}_{12}\text{H}_{15}\text{O}_2$ 191.1067; Found 191.1058.

5-phenyldihydrofuran-2(3H)-one (**5f**) and 4-oxo-6-phenylbutanal (**6f**)

From **3f** (59 mg, 0.26 mmol) using general procedure D, 5-phenyldihydrofuran-2(3H)-one **5f** and 4-oxo-6-phenylbutanal **6f** was obtained as a 1:1 inseparable mixture (31 mg, 73%), as a colorless oil. Chromatography eluent: Petroleum Ether/AcOEt 85/15. Further attempts to separate both compounds led to the degradation of aldehyde 4-oxo-6-phenylbutanal **6f**. Full characterization could be made on **5f**. ^1H NMR data of **6f** deduced from the isomeric mixture of **5f/6f** agreed with the literature.¹⁶

5-phenyldihydrofuran-2(3H)-one (**5f**)¹⁷

IR (cm^{-1}): 2922, 2850, 1770, 1215, 1174, 1139, 1020, 939, 758, 700.

^1H NMR (300 MHz, CDCl_3) δ 7.44 – 7.28 (m, 5H), 5.52 (dd, J = 8.1, 6.1 Hz, 1H), 2.72 – 2.60 (m, 3H), 2.19 (tt, J = 8.2, 4.0 Hz, 1H).

^{13}C NMR δ 177.0, 139.6, 128.9, 128.6, 125.4, 81.3, 31.1, 29.1.

4-oxo-6-phenylbutanal (**6f**)¹⁶

^1H NMR (300 MHz, deduced from the mixture of constitutional isomers **6f** and **7f**, CDCl_3) δ 9.91 (t, J = 0.6 Hz, 1H), 7.99 (dd, J = 7.3, 1.5 Hz, 2H), 7.58 (tt, J = 7.3, 1.3 Hz, 1H), 7.47 (tt, J = 7.3, 1.3 Hz, 2H), 3.33 (dd, J = 7.0, 6.1 Hz, 2H), 2.93 (t, J = 6.3 Hz, 2H).

HRMS (ESI, mixture of constitutional isomers **6f** and **7f**) m/z : calcd for $[\text{M}+\text{Na}]^+$ $\text{C}_{10}\text{H}_{10}\text{O}_2\text{Na}$ 185.0573; found 185.0575.

5-(2-chloro-6-fluorophenyl)dihydrofuran-2(3H)-one (**5g**)

From **3g** (214 mg, 0.78 mmol) using general procedure D, 5-(2-chloro-6-fluorophenyl)dihydrofuran-2(3H)-one **5g** was obtained as sole product and as a colorless oil (138 mg, 83%). Chromatography eluent: Petroleum Ether/ Et_2O 70/30.

IR (cm^{-1}): 2974, 1775, 1607, 1576, 1456, 1182, 891, 785.

^1H NMR (300 MHz, CDCl_3) δ 7.27 (td, J = 8.1, 5.8 Hz, 1H), 7.20 (ddd, J = 8.1, 1.5, 0.8 Hz, 1H), 7.03 (ddd, J = 10.6, 8.0, 1.5 Hz, 1H), 6.04 (tt, J = 7.5, 1.0 Hz, 1H), 2.87 – 2.58 (m, 3H), 2.44 (m, 1H).

^{13}C NMR (75 MHz, CDCl_3) δ 176.76, 161.86 (d, J = 252.5 Hz), 134.21 (d, J = 5.6 Hz), 130.74 (d, J = 10.2 Hz), 126.12 (d, J = 3.5 Hz), 125.00 (d, J = 13.6 Hz), 115.37 (d, J = 22.7 Hz), 75.34, 28.68, 27.30.

HRMS (ESI) m/z : calcd for $[\text{M}+\text{H}]^+$ $\text{C}_{10}\text{H}_9\text{ClFO}_2$: 215.0270; Found 215.0271.

5-(4-methoxyphenyl)dihydrofuran-2(3H)-one (**5h**) and 4-(4-methoxyphenyl)-4-oxobutanal (**6h**)

From 6-(4-methoxyphenyl)-1,2-dioxan-3-ol **2h** (134 mg, 0.64 mmol), a mixture of **5h** and **6h** was obtained instead of **3h** using the general procedure C. Thus **5h** and **6h** were obtained as a 1:4 inseparable mixture (36 mg, 23%), as a colorless oil. Chromatography eluent: Petroleum Ether/AcOEt 80/20. ^1H NMR data of **6h** deduced from the isomeric mixture of **5h/6h** agreed with the literature.¹⁸

IR (mixture of isomers **5h** and **6h**, cm^{-1}) : 2922, 2841, 1771, 1719, 1672, 1599, 1510, 1244, 1169, 1028, 831.

5-(4-methoxyphenyl)dihydrofuran-2(3H)-one (**6h**)¹⁸

^1H NMR (300 MHz, deduced from the mixture of isomers **5h** and **6h**, CDCl_3) δ 7.19 (d, J = 8.6 Hz, 2H), 6.92 – 6.81 (m, 2H), 5.39 (m, 1H), 2.60 – 2.33 (m, 3H), 2.16 – 1.94 (m, 1H).

methoxyphenyl)-4-oxobutanal (**6h**)¹⁹

^1H NMR (300 MHz, CDCl_3 , deduced from the mixture of isomers **5h** and **6h**) δ 9.83 (t, J = 0.8 Hz, 1H), 7.89 (d, J = 8.6 Hz, 2H), 6.87 (d, J = 8.6 Hz, 1H), 3.80 (s, 3H), 3.21 (t, J = 6.4 Hz, 2H), 2.83 (t, J = 6.4 Hz, 2H).

^{13}C NMR (75 MHz, CDCl_3 , deduced from the mixture of isomers **5h** and **6h**) δ 200.9, 196.4, 163.8, 130.5, 127.1, 114.0, 55.6, 37.9, 30.9.

HRMS (ESI) for the mixture of **5g** and **6g** calculated for $\text{C}_{11}\text{H}_{12}\text{O}_3\text{Na}$ $[\text{M}+\text{Na}]^+$: 215.0684; Found 215.0660.

Preparation of 1,2-dioxolanyl-3-acetates **7a-b**. General Procedure E

To a round bottom flask containing a solution of cyclopropanol (1 equiv.) in MeCN (1 mL/mmol), 0.5 mol% $\text{Mn}(\text{acac})_3$ was added. The reaction mixture was then stirred under an atmosphere of oxygen. After 2 h at rt, pentane was added, precipitating most of the metal salts. The solution was filtrated on a silica pad and was rinsed with Et_2O several times. Volatiles were removed under reduced pressure to give crude 1,2-dioxolan-3-ol **7a-b**. Note: An external cooling (cold water) might be needed in case of gram-scale reactions, not to exceeding -35 °C.

Acetylation was then performed in a second step using general procedure B.

Preparation of compound **7a** was already reported by us in a previous study.⁹

1,2-dioxaspiro[4.5]decan-3-yl acetate (**7b**)

From spiro[2.5]octan-1-ol²⁰ (152 mg, 1.2 mmol) using general procedure D, 1,2-dioxaspiro[4.5]decan-3-yl acetate **8b** was obtained as a colorless oil (87 mg, 36%) over 2 steps). Chromatography eluent: Petroleum Ether/ Et_2O 90/10.

^1H NMR (300 MHz, Chloroform- d) δ 6.46 (dd, J = 6.2, 1.5 Hz, 1H), 2.74 (dd, J = 13.3, 6.2 Hz, 1H), 2.37 (dd, J = 13.3, 1.6 Hz, 1H), 2.10 (s, 3H), 1.83 – 1.61 (m, 6H), 1.60 – 1.34 (m, 4H).

^{13}C NMR (75 MHz, CDCl_3) δ 170.3, 97.3, 84.7, 51.9, 35.8, 34.2, 25.2, 24.5, 23.2, 21.3.

HRMS (ESI) m/z : calcd for $\text{C}_{10}\text{H}_{16}\text{O}_4$ $[\text{M}+\text{Na}]^+$: 223.0946; found 223.0827.

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Supporting Information

Copies of ^1H and ^{13}C NMR spectra for newly described compounds.

Primary Data

NO

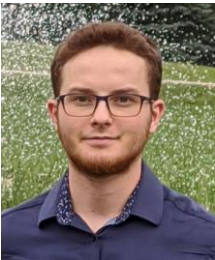
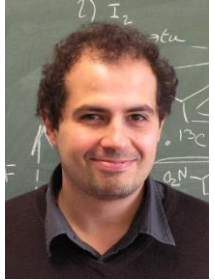
Conflict of Interest

The authors declare no conflict of interest. The authors declare no conflict of interest. The authors declare no conflict of interest.

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Biosketches

	<p>Nicolas Jamey studied at the École Nationale Supérieure de Chimie de Mulhouse and graduated as double diploma his master's degree at the Université de Sherbrooke in 2020, where he worked with Prof. Claude Spino on the synthesis of α-hydroxy acids by 1,3-transposition of allylic alcohols catalyzed by Rhenium. He moved to Paris to pursue a Ph.D. under Laurent Ferrié in Biocis at Université Paris-Saclay.</p>
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